ELEMENTS

OF

CHEMISTRY,

ILLUSTRATED BY

MORE THAN ONE HUNDRED ENGRAVINGS.

DESIGNED ESPECIALLY

FOR THE USE OF

SCHOOLS AND ACADEMIES.

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NEW-YORK:

M'ELRATH & BANGS,

No. 29 Ann-street.

1835.

Osborn & Buckingham, Printers,
No. 29 Ann-street.

INTRODUCTION.

It has been the lot of the author of the following pages, during the last seven years, to be devoted to teaching Chemistry as a science. He has, in common with many others of the same profession, suffered much inconvenience from the want of a suitable text book. The works designed for this purpose, and which have obtained the most extensive circulation, are Comstock's Elements and Jones' Conversations. The latter is a most interesting and valuable book, and had it been written in any other form than that of a dialogue, the author would not have been compelled to apologize for writing a book. It is a universal complaint with teachers, that the Conversations is much curtailed in its usefulness from the form in which it is presented, conversations being generally considered by teachers as unsuitable for school books.

The work by Comstock, though expressly designed to supply the wants of teachers, is very far from having accomplished that object:—to beginners it is often obscure, and frequently unintelligible. Abounding as it does with so many heterogeneous compilations from different authors, whose works were frequently designed for very

different purposes, it was impossible to avoid irregularities in the character of the work; hence we find in some parts a prolixity of scientific detail, equal in length and minuteness to that of the most elaborate treatises. Take as an example, the chloride of lime or bleaching powder, which subject occupies more space in this little book of 345 pages, than in any other treatise I have seen. The celebrated work of Dr. Turner, containing 990 pages octavo, gives a full and complete description of the same article in three times less space. The chapter on chemical attraction or affinity is extended beyond all reasonable limits, thirty pages being devoted to a department which should have been despatched in fifteen, or twenty at most. The defects above named, in the works designed for the use of schools, are the chief reasons which have induced me to prepare for the press a work, which, it appears to me, is much needed. From a continued and almost exclusive devotion to the laboratory and lecture room, for the last six or seven years, it will, I presume, be acknowledged, that I have had an opportunity of appreciating, in some degree at least, the wants of the public in this respect.

It has been a serious objection to the introduction of chemistry into schools, that the works devoted to that subject were so large, and often uninteresting, the pupils being discouraged at the onset, from the apparent laborious undertaking. To remove such objections, I have endeavored

to confine myself to the plainest and most obvious laws and principles, omitting those of a more complicated nature, or, that are not especially adapted to the wants and capacities of the common and boarding school pupil. I have accompanied, as far as practicable, every principle or law with an experiment or observation for illustrating the text, printed in smaller type, being satisfied that one or two experiments for illustrating a principle, if simple and easily performed, is much better than more, though equally well devised.

As the work was not intended as a manual for the experimenter, nearly every thing relating to manipulation and necessary for the teacher only is left out; because such matter was considered unnecessary, as the mind of the pupil should be directed rather to the principles of the science than to the methods of experimenting. The experiments described are of that simple character that no teacher ought to fail in performing. This is a point that has not been sufficiently attended to in works hitherto published, a circumstance which, it is believed, has been a great obstacle in preventing teachers from giving practical illustrations to their pupils.

New-York, Dec. 1834.

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ERRATA.

Page 50, line 13 from top, for 79 read 89.
65, Light should be headed by *Chapter* II.
71, Electricity " " " III.
74, line 10 from top, for farther read *feather*.
78, " 8 " read *by* glass legs.
100, " 16 " read *acetic*.
128, " 24 " " 252.
128, " 30 " " 253.
128, Questions 253-4, read 252-3.
233, line 9 from top, read *amalgam*.
237, " 6 from bottom, read *M. Bussy*.
250, line 12 from top, read *volatility*.

GENERAL REMARKS.

ALL substances with which we are acquaint-re endowed with two kinds of properties, *ical* and *chemical*. The former belong to *ural Philosophy*, the latter to *Chemistry*. former considers matter in masses, and cially treats of its motions as perceptible to ye, while the latter considers it as made up inute particles, and treats of those motions h are generally imperceptible to the eye.

st. 1. If a loaf of bread, as mentioned by Mrs. Marcet, be ito slices, or grated down, the operation is mechanical, elongs to natural philosophy; but if it could be separated ie flour, the yeast, the water, and the salt, which composed process would be chemical.

A piece of marble may be broken by a hammer into the st fragments, the operation would still be mechanical; ch particle, however small, is of the same nature and ses the same properties as the rest. If however, the e be heated to redness, a quantity of fixed air or carbonic expelled, leaving common quick lime; if the heat could e sufficiently increased, another kind of air called oxygen ould be driven off, and a pure white metal resembling sil-ould remain.

e operation of the hammer developes the physical, while f heat developes the chemical properties of marble.

Chemistry is that science which treats of

escribe the two classes of properties ?—Describe illustration first? be illustration second ?
That is chemistry ?

the combination and decomposition of bodies, and of the properties which they acquire by such changes.

Obs. As chemists are chiefly confined in their operations to heat and mixture, this science has frequently been termed "the science of heat and mixture."

3. All bodies have been divided into two great classes *imponderable** and *ponderable;* the former includes light, heat, and electricity; while the latter includes all other varieties of matter.

4. Bodies are also divided into ***simple*** and ***compound:*** a simple body is one whose particles are all of the same kind.

Illust. A piece of lead may be hammered, cut into the minutest fragments, or melted, still it possesses the properties common to lead in general, for it contains no other substance. If we had found intimately combined and melted with it a quantity of copper or tin, it would no longer be a simple body but a compound: hence,

5. A compound body is one that is made up of two or more simple ones.

6. The methods used by chemists to separate the parts of a compound body, are termed ***analysis***, while those used to combine the ingredients and form a compound, are called ***synthesis***.

Illust. By synthesis we unite the metals copper and zinc to form brass; by analysis we expose the brass to a white heat, the zinc goes off in vapor, and pure copper is left.

7 The number of simple or elementary bodies

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3. How are bodies divided, and what are the imponderable?
4. Define simple and compound bodies?
6. Define analysis and synthesis?
7. How many simple bodies?

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* Imponderable bodies are such as have no perceptible weight, while ponderable are such as can be weighed.

(except the imponderable ones) is fifty-four—thirteen of which are non-metallic and forty-one are metals.

8. The subject of the simple or elementary bodies with their various artificial combinations is frequently denominated *inorganic chemistry*, to distinguish it from that part which treats of animals and vegetables, and which is called *organic chemistry*.

9. The subject of this treatise will be divided into five parts.

Part 1. THE IMPONDERABLE AGENTS.
2. NON-METALLIC COMBUSTIBLES.
3. THE METALS.
4. VEGETABLE CHEMISTRY.
5. ANIMAL CHEMISTRY.

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8. Describe organic and inorganic chemistry?
9. How is the treatise divided?

PART I.

IMPONDERABLE AGENTS.

CALORIC, LIGHT, AND ELECTRICITY.

CHAPTER I.

Caloric.

10. CALORIC is generally considered as a material agent, and as such it is described as a very subtile fluid which emanates from all heated bodies in the same manner as light is emitted from all luminous bodies; that is in straight lines. It is so light that our most delicate balances indicate no perceptible weight in it, and hence it is called *imponderable.* It is very intimately connected with light and electricity, and it is quite possible that the phenomena of all three may hereafter be found to originate from one common cause.

11. In the present work Caloric will be considered as a material substance, without entering into the arguments for or against this opinion.

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10. Describe caloric and its connexion with light and electricity.
11. How is caloric regarded by the author?

12. Heat is a term applied to the sensation produced in us by a hot body. It is therefore one of the effects of caloric, and exists in us rather than in the hot body: hence the truth of the remark that there is no heat in fire.

13. All bodies when heated give out caloric to those of a lower temperature: thus when we apply the hand to a hot body, a part of its caloric is imparted to the hand and excites in us the sensation of heat; if, on the contrary, the hand be plunged into cold water, it will give up a part of its caloric to the water producing in us the sensation of cold.

14. Caloric will be treated under the following heads: *radiation*, *conduction*, the *effects* of caloric, *specific caloric*, and the *sources* of caloric.

All heated bodies impart their caloric in two modes, called radiation and conduction. By *radiation* we mean the instantaneous passage of caloric from a heated body through space; by *conduction*, we mean the slow transmission of it from one portion to another of the same body, or from one body to another that is in contact.

RADIATION.

15. Caloric is radiated from the surface of a hot body in all directions and in straight lines, precisely in the same manner as light is emitted from all luminous bodies. It passes with equal

12. What is the difference between heat and caloric?
13. What effect is produced by heating bodies, and how illustrated?
14. How is caloric divided?
15. Describe radiation of caloric?

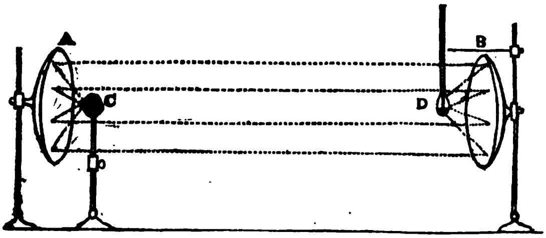
freedom through air, every species of gas, and through a vacuum.

16. Rays which emanate from heated bodies, whether luminous or not, may be reflected in the same manner as light, and are susceptible of many economical applications.

Illust. It is to radiant caloric that we are indebted for the warmth and comfort of our apartments in winter, stoves and fire-places being generally so constructed as to throw out the heat into the room.

17. That heat radiates from bodies in straight lines may be illustrated by the experiment with the concave mirrors, which are placed opposite each other, and about ten feet apart; thus,

A and B, the mirrors; C, the hot iron ball; and D, the air thermometer with its scale.



Exp. 1. The calorific rays proceeding from C, fall upon the mirror A, and are reflected from it in straight lines to the mirror B, where they are again reflected in such a direction as to meet at the point D, which is called the focus, and in which is placed a delicate air thermometer, the air being expanded in the bulb, forces the liquid up the stem in proportion as the temperature is elevated.

Exp. 2. If we vary the experiment by putting in the place

16. What are the properties of the calorific rays, and how is it illustrated?
17. What illustrates the reflection of caloric?—Describe Exp. 1, 2, 3.

[illegible] hand successively to a piece of [illegible] [illegible] which have been exposed to an oven [illegible] [illegible] flannel can be borne [illegible] [illegible] iron will be intolerable [illegible]

34. It is a general rule that the densest bodies [illegible] hard wood, &c., are better con- [illegible] the more porous, such as flannel, [illegible] &c.

35. As a class of bodies, the metals are the most perfect of all conductors. According to the experiments of Ingenhouz, silver, gold, and copper, are superior, while iron, platinum, and lead, are greatly inferior.

Exp. The accompanying wood cut indicates a metallic instrument for illustrating the relative conducting power of different metals, and consists of a circular piece of brass *a* with a hole in the centre, and containing a number of bars of different metals, each having a small cavity in its extremity for holding a piece of phosphorus; having supplied each cavity with phosphorus, the central piece *a* is held over the flame of a spirit lamp, and the caloric conducted along the different metallic rods will inflame the phosphorus in that first which is the best conductor, and so of the others according to their conductibility.

36. Next in conducting power to the metals, stand the different gems, as diamond, topaz, ruby, &c. Their conductibility being nearly in the order of their value. Next to these the different earths, marble, clay, sand-stone, glass, and earthenwares. The poorest of all solid conductors are the different animal coverings, as hair, wool, feathers, &c.

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34. What rule for the conducting power of bodies?
35. What is said of the metals? What experiment is made?
36. Mention the order of the conducting power of different bodies.—Illustration 1.—Illustration 2?

Illust. 1. We can distinguish diamond from rock-crystal, by applying them successively to the tongue. The diamond will feel coldest, because it is the best conductor.

2. At the siege of Gibraltar, red hot iron balls were carried from the furnaces to the bastions, a considerable distance, on wooden wheelbarrows, having a thin layer of sand between them and the balls.

37. Glass is a poor conductor, and when heated suddenly, unless very thin, it is liable to break; hence a thick glass vessel should never be placed suddenly upon burning coals, though the experiment may be made with impunity upon a Florence flask, because the glass is very thin.

Rationale. When a piece of thick glass is exposed suddenly to the flame of a lamp, the part which is in contact is heated rapidly and considerably expanded, while those parts at a little distance, from the poor conducting property of the glass, are scarcely heated at all, and as the glass is exceedingly brittle and unyielding, it is broken, from the irregular expansion.

38. Dry wood is a poor conductor, hence wooden handles are often used for metallic utensils. The difference between the conducting power of wood and metal is illustrated in the following experiment:

Exp. Procure two similar solid cylinders about an inch and a half in diameter, and eight or ten in length, the one of wood and the other of metal; wrap a single thickness of writing paper closely around each. The metallic cylinder may now be exposed to the flame of a spirit lamp for nearly a minute without even scorching the paper, while the wooden cylinder similarly exposed will have its paper cover scorched instantly. Here the high conducting power of the iron carries off the caloric as fast as received, while the wood being an imperfect conductor allows it to accumulate, and thus the paper is burnt.

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37. What is said of the breaking of glass?
38. What is said of wood in relation to conduction?—What is the experiment?

Charcoal is an extremely bad conductor, and on th
is frequently used to prevent ice from melting in s
covering it over with powdered charcoal.

39. All solids in masses are much bett
ductors than when broken into fragment
solid rock conducts much better than sa
gravel.

40. Amongst substances employed as a
of clothing, hare's fur and down of the
duck are the best, and hemp and flax ar
poorest conductors.

41. The relative conducting power of
different substances, seems to depend upon
relative quantities of air enclosed in their po
or perhaps upon the greater number of pore
those that are better conductors, as air is mu
inferior in this respect to any solid body.

Obs. 1. Hence the benevolence of the Creator is appar
in supplying those animals that inhabit cold climates with
abundance of fur, and what is quite remarkable, the bene
lence of the design is carried out to the minutest details. Th
we see that animals are supplied with fur in abundance a
fineness in exact proportion to the coldness of the region th
inhabit; and the fur is always finer in winter than in summe
as well as more abundant, answering to the convenience an
comfort of the animal.

2. Those substances that form the warmest articles of cloth-
ing are such as have the longest nap or fur on account of the
air enclosed, which has a tendency to prevent the escape of the
natural warmth of the body.

3. The imperfect conducting power of snow arises from the
same cause, and answers most benevolent purposes in protecting
plants from the severity of winter. In Siberia, while the tem-

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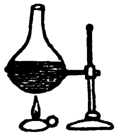
39. What is said of the conducting power of solids in masses or in
fragments?
40. What is said of the conducting power of hemp and elder down?
41. Why does hemp conduct better than eider down?—What is the sub-
stance of observations 1, 2, 3?—What is the substance of observation 3?

perature of the air has been 70° below the freezing point of water, the surface of the ground protected by its covering of snow has been seldom found below the freezing point. Here the snow being an imperfect conductor, will not permit the caloric of the earth to pass through it into the atmosphere.

42. The conducting power of liquids* and gases is very limited, though they appear to conduct, the caloric is transmitted through them quite rapidly in an upward direction, by interchange of the particles.

Obs. Hitherto no single term has been used to designate this peculiar method of communicating caloric, for which Dr. Prout has lately proposed the term *convection*, which signifies a carrying or conveying of the caloric away, which term will be adopted here. This principle may be illustrated as follows:



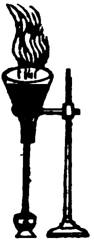
Exp. Fill a large glass flask, of the capacity of at least two quarts, about half full with water, and throw into it a few fragments of amber or silver leaf, or any other substance that will float in water; now apply the flame of a spirit lamp to the bottom of the flask, and we shall soon perceive, by the movement of the solid particles, that those parts of the liquid nearest the bottom are first heated, expanded, and thus becoming lighter ascend to the surface; and the colder and heavier ones from the surface descend, and in their turn become heated and re-ascend to the surface, and thus by the convection or carrying of the particles, the liquid becomes heated. In a large vessel there will be seen a current in the middle ascending, and another or others at the sides descending at the same time. See the accompanying wood cut.

43. By convection caloric is propagated through liquids in an upward direction only: hence almost any degree of heat may be ap-

42. Do liquids and gases conduct?—Explain the term here used.—Describe the experiment.
43 What is the remark made on convection?

* Except the liquid called mercury or quicksilver.

plied to the surface of liquids without materially the lower strata.



Exp. 1. Into a glass funnel fit a tube having a large bulb, and containing of some colored liquid in the stem, whic into a cup containing a quantity of the and the whole supported on a stand as in the accompanying figure. Pour wa funnel until it covers the bulb of the the the depth of a quarter of an inch, and u face pour a small quantity of ether and Much caloric is given out in the combu ether, yet the water will not transmit it in sufficient quantity to affect the therm

Exp. 2. The same principle may be still more stri bited by varying the experiment as first communi by Dr. Ellet of this city. A thin glass or porcela taining as much water as that in the funnel, is su the stand over the ether. (in Exp. 1.) After the ethe a thermometer is applied to the water in the funn to that in the cup above it—the difference of temper two portions of water will indicate the caloric comn each; when it will be found that the heat communi upper vessel, will exceed by many times that comm the lower one.

Exp. 3. Put some water into a thin open at one end, and hold it over a sp represented in the wood cut, the upper boil violently, while those near the bott be heated at all.

44. Quicksilver is the only liquid th pable of conducting caloric in any con degree; hence bodies cool much faste liquid than in water, because being conductor it carries off their caloric r pidly.

Illust. For instance water will communicate suffi

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44. What is said of the conducting power of quicksilver ?

to the hand to scald it at the temperature of 130°, but quicksilver will produce the same effect at 120° : hence quicksilver will feel as hot at 120° as water at 130°.

45. Air and all gaseous substances are much poorer conductors than solids or liquids, and it is even doubted whether they conduct at all; though they may be heated rapidly by *convection* or the interchange of their particles.

Illust. If the lowermost strata of air in a room be heated, the particles thus heated become specifically lighter than the rest, and ascend to the upper part of the room, while colder and heavier ones descend to supply the defect. These in turn are heated, expanded, and ascend in the same manner. The common impression, therefore, that air is a good conductor, says Prof. Silliman, is erroneous. It is a good carrier of caloric, but not a conductor.

46. Confined air impedes the progress of caloric; hence, double doors and windows containing confined air between them are useful in preserving a uniform temperature in our dwellings in winter, by preventing the ingress of cold and the egress of heated air.

47. In rooms heated by fires, different currents of air may be detected by opening the door a few inches, either from the hall or from a cool apartment, and holding a lighted candle in the draught. Near the upper part of the door the current will be outward, because the lighter and more expanded air in this vicinity is forced out by its own expansion as soon as the door is

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45. What is the conducting power of air and gases?—Give the illustration.
46. What is said of double doors?
47. How are the currents of air detected in rooms heated by fires?

opened, but if held near the floor the current will be in the contrary direction; if the flame be held about midway between these extremes, it will be irregular and much less than either of the others, but sometimes inward and sometimes outward.

EFFECTS OF CALORIC.

These are three—expansion, liquefaction and vaporization.

48. *Expansion.* No fact is probably more familiarly known than the expansion of bodies by heat. If the assumed fact that caloric is material be true, it is a consequence necessarily resulting from it, that when it enters or insinuates itself between the particles of bodies, they should be forced further apart and the body be expanded.

Exp. This is illustrated by heating the air in a common thermometer bulb, having plunged the open end of its tube into a vessel of water as represented in the figure, the expanded air is forced out and rises through the water.

Obs. 1. If a piano, harp, or any other stringed instrument be tuned in a cold room, and the room be afterwards heated the instrument will be put out of tone from the unequal expansion of the strings.

2. The pendulum of a clock or timepiece is longer in summer than in winter, hence it will be a longer time in performing a vibration, and consequently the instrument will lose time in summer and gain in winter.

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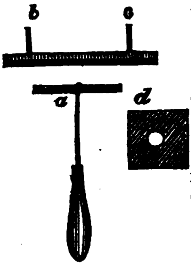
48. What are the three effects of caloric?—Describe the experiment?—What observation is made on stringed instruments?—What remark on the pendulums of clocks?

49. Air is expanded eight times more than water, and water about forty or fifty times more than iron.

Exp. 1. The simplest way of showing the expansion of liquids, is by plunging a common thermometer into a vessel of hot water, and observing the height at which the fluid in the stem rises; and on removing it we shall find as it cools it will sink to the former level, thereby proving that bodies are expanded by heat and contracted by cold. It is on this principle that thermometers are constructed.



Exp. 2. The expansion of solids may be exhibited by fitting an iron rod *a*, so that when cold it will pass freely between a couple of pillars *b* and *c*, and one of its ends will also fit into the hole of the iron plate *d*, and by slightly heating the rod it will be so much enlarged as to prevent it from fitting between the pillars or in the hole of the iron plate; but on cooling it will be received in both.

50. Instruments used to show the expansion of solids by heat are called *pyrometers*, those used to show the expansion of liquids, *thermometers*, terms taken from the Greek, the former signifying literally a *measurer of fire*, the latter a *measurer* of *heat*. The instrument exhibited in the above experiment may be considered a pyrometer.

51. Amongst solids the metals are the most expansible by heat, zinc and lead being the most,

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49. What is the comparative expansion of air, water and iron?—Describe Exp. 1 and 2.

50. What are pyrometers and thermometers?

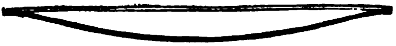
51. What metals are most and what the least expansible?—Describe the experiment.

and platinum and iron the **least expanded by** the same degree of heat.

Exp. The difference between the **expansibility of zinc and** iron may be exhibited by forming a compound **bar of these two** metals by riveting them together at the ends, or by **soldering as** seen in the figure.

1. 

2. 

3. 

No. 1. Exhibits the compound bar before being **heated.**
No. 2. The same bar heated by a lamp. The two **metals are** soldered together.
No. 3. The two metals are united by riveting **at each end,** and then heated by a lamp.*

52. There are many mechanical operations in which the expansion by heat and contraction by cold are rendered subservient.

Illust. 1. Barrels and other casks for containing liquids are held together by iron hoops made a little too small for the **cask** when cold, but are heated until they are sufficiently **expanded** to be received in their places when they are suddenly driven on

52. How does expansion apply to hoops upon casks?—What illustration is applied to carriage wheels?—What to the removal of glass stoppers from bottles?—How is the expansion of glass shown?

* The experiment with the two metals as exhibited in No. 3, may be made by riveting a narrow strip of sheet zinc (such as is used to cover roofs of houses, &c.) to a similar strip of sheet iron, or even common tinned iron. They should be riveted only at the ends.

and cooled by dashing on them cold water. The metal contracted and binds the staves firmly together.

2. The parts of carriage wheels are bound together by the iron band called the tire, in a similar manner. The tire is first heated until it is sufficiently expanded to be brought over the wood, when it is cooled as above described, and binds the parts of the wheel together with great force.

Exp. 1. The expansion of glass may be thus shown.

Fill a florence-flask with water, and insert the stem of a thermometer tube into the neck, so [illegible] as to enter the liquid and permit it to rise [illegible] in the tube; now drop in a little colored alcohol [illegible] on the column of water in the stem, and [illegible] projecting part of the tube fix a paper scale divided into equal parts. Having prepared a vessel of boiling water, plunge the flask into it, nearly to the neck, and the column of liquid will instantly sink a number of degrees in the tube from the sudden expansion of the flask; but if it be allowed to remain a few moments in the water, until that within the flask begins to expand, the column will begin to ascend in the tube.

2. We often make use of the principle of expansion in removing glass stoppers from vials. The most successful method of which is to heat the neck of the vial by holding it directly in the flame of a spirit lamp for a moment or two, and turning it round constantly, which will heat and expand the neck before the stopper is affected, when it may be removed with ease. Another method consists in heating the neck by friction with a small chord or string, but it is less successful.

53. The expansibility of liquids is very different. Ether expands more than alcohol, alcohol more than water, and water more than mercury, by the same degree of heat.

54. The rate of expansion in liquids by equal additions of heat is a constantly increasing one; that is, by adding one degree of heat near the freezing point of water, it will expand

53. What is said of the expansibility of different liquids?

54. What is the rate of expansion?—What is said of [illegible] in relation to expansion.

[illegible] less than by adding the same amount near the [illegible]ing point.

[illegible] difference of the expansive power of liquids at [illegible] temperatures, is less observable in mercury than [illegible] other fluids. Hence it is the most suitable liquid for [illegible].

55. There is one very remarkable exception to the law of expansion of liquids by heat and contraction by cold: in this respect water differs from every other liquid; for if we take a quantity of it at the temperature of 40°, and heat it or cool it below that temperature, in either case it will expand. Hence water at 212° the boiling point, cooled down to 32° the freezing point, will constantly contract until it reaches the temperature of 40°, when it will begin to expand, and continue to do so until it arrives at 32°, and begins to freeze.

56. This exception to the uniform expansion of liquids by heat, is to be looked upon not merely as a curious philosophical fact, but as a design of the Creator to accomplish one of the wisest and most benevolent of purposes; namely, the preservation of the lives of fishes and all other animals that inhabit the waters of cold climates, by preventing lakes and rivers from freezing, except on the surface.

Illus. Suppose a fresh water lake in summer to be at the temperature of 70°; in the autumn as the cold breezes blow over it, the upper strata give up their caloric to the air, which carries it away; the water as it cools contracts and becomes

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55. What exception to the law of expansion?

56. What is the design manifested in this remarkable exception?—Give the illustration.

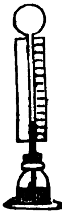
heavier than the lower strata; consequently, as the upper strata are cooled, they become heavier and descend, while the lower, becoming comparatively lighter, ascend, give off their caloric, and sink again to the bottom. These changes go on until the whole lake is cooled down to the temperature of 40°. The time required to accomplish this will depend entirely on the depth of the lake, and consequently on the quantity of the water to be cooled.

When the whole lake has cooled down to 40°, at which temperature the water is denser than at any other, the strata which are uppermost still give off their caloric, but instead of becoming denser by this process, as before, they become lighter, and consequently remain on the surface until it is reduced to the freezing point, while the lower strata, or those near the bottom, remain at the temperature of 40°, which is sufficient to preserve the lives of the fishes and other aquatic animals.

In some cases lakes are so deep that they do not lose caloric enough to reduce them to the freezing point during the whole winter.

57. It was before stated (49) that thermometers are constructed on the principle of expansion by heat, and contraction by cold: we shall now proceed to describe the most simple thermometers, and those in most general use.

58. The invention of the thermometer is generally attributed to Sanctorio, an Italian physician, of the seventeenth century. The instrument invented by him, differs however from those in common use. In the former the instrument is filled with air, while in the latter mercury is used. The first is therefore called an air thermometer, (the construction of which may be understood



by inspecting the accompanying wood

58. Who was the inventor of thermometers, and how does it differ from those now in use?

cut,) while the latter is called the r thermometer.

59. There are two objections to the th ter of Sanctorio: 1st. the dilatation is that the length of tube required where th of temperature is considerable, render strument inconvenient: and 2dly, it is by the pressure of the atmosphere, wh varies without much affecting the tem

60. Fahrenheit, of Amsterdam, was the first to modify and improve the ins of Sanctorio; he indeed claims the i and introduction of the kind of ther now in general use. He substituted for air, in filling the instrument, which him to use a much smaller instrument same degree of accuracy; but it was s defective, inasmuch as no two instrumen ed in this way would agree in their res cause there were no fixed points to gu maker in graduating the scales.

61. Sir Isaac Newton was the first to the plan now in use for obtaining tl points, founded on the fact that ice c melts, and water, under similar circum boils at a uniform temperature, conse these two were made the fixed points fro to graduate the scales of thermometers.

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59. What objections to the thermometer of Sanctorio?
60. What is said of Fahrenheit?
61. What was Newton's suggestion?—Describe the divisio heit's scale—and why the zero happened to be at 32° below water.

renheit's scale, the space between freezing and boiling water is divided into 180 equal parts: water freezes at 32°, and boils at 212°. The zero or commencement of the scale was the result of accident. During the course of Fahrenheit's experiments on the thermometer, he made a visit to Iceland, and while there fixed upon the temperature he then experienced as the greatest cold that would probably be produced by artificial means, and consequently a suitable point for the zero of his thermometer; and this was afterwards ascertained to be the same temperature produced by mixing snow and common salt.

Obs. Though we now obtain, by artificial means, temperature of 90° below zero, and in the region of Hudson's Bay, the atmosphere has been at 50, and occasionally at 55 degrees below; still the original zero of Fahrenheit, which is 32° below the freezing of water, has been retained. And when speaking of degrees of heat or cold in this treatise, unless the kind of thermometer be mentioned, it will be understood that we mean Fahrenheit's.

62. In *Reaumur's* scale, the freezing point of water is zero, and the boiling point 80°; and the degrees above and below these points are made of the same size,—used formerly on the continent of Europe.

63. In the *centigrade* thermometer, now almost the only instrument used in France, the space between the two fixed points is divided into 100 equal parts. Water freezes at zero and

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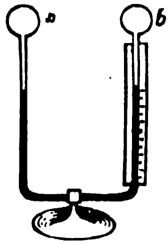
62. Decribe Reaumur's scale.
63. Describe the centigrade.

boils at 100° ; corresponding degrees a
on the scale, above and below the fixed

64. *De Lisle's* thermometer makes t
ing point of water zero, and the freezi
150° ; chiefly used in Russia.

65. There is still another kind of the
ter, intended only to indicate slight cha
temperature, invented by the late Count
ford, and denominated by him a *thermo*.
It was improved by Mr. Leslie, and call
him the *differential thermometer*, the
modern and improved fo
which, may be seen in th



companying wood cut. It
sists of two bulbs, *a* and *b*, c
taining vapor of ether, wh
is much expanded by slig
elevation of temperature. T
bulbs are connected by a tu
twice bent at right angles, a
containing a small quantity
colored sulphuric ether. The tube is supported
a wooden foot or stand. When a warm body,
the hand, is brought near one of the bulbs, as
the vapor which fills the bulb and upper part
the tube is expanded, forcing the column of
quid downward on the side *b*, and upward
the side *a*.

Obs. It will be seen that the differential thermometer is o

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64. Describe De Lisle's.

65. What is the *thermoscope*, and what the differential thermometer
Describe the differential thermometer.—What is the use of this ins
ment ?

calculated to indicate the difference of temperature between the two bulbs, and is therefore not at all affected by any changes of temperature in the surrounding atmosphere, because such changes operate equally upon both bulbs.

66. An air thermometer, simpler in its construction, larger, and therefore better adapted to class experiments to be witnessed at a distance, may be seen in the figure. It is constructed by thrusting a small glass tube, sixteen or eighteen inches long, through a cork which is inserted into the mouth of a common oil flask, containing about an ounce of some colored liquid; the junctures about the cork being made tight by means of cement. By applying heat to the bulb, the air within is expanded, and forces the column of liquid up the stem.

Obs. This thermometer is particularly useful in showing the reflexion of caloric by means of the concave mirrors.

67. The kind of fluid used for filling thermometers depends on the uses to which it is to be applied. For all common purposes, and for all temperatures from the melting point of lead down to 40° below zero, mercury is most generally used.* If we have occasion to measure greater degrees of cold, spirits of wine (which has

66. Describe the air thermometer.
67. What fluids are used in thermometers?—*Obs.* What information do we obtain by thermometers?

* Another reason why mercury is used, is on account of its more uniform expansion by equal additions of heat at different temperatures than most other liquids.

never yet been frozen) is substituted. In differential and other thermometers calculated for slight variations of temperature, ether, alcohol, or atmospheric air is made to supply the place of mercury.

Obs. Though the thermometer is an exceedingly valuable philosophical instrument, still the amount of information conveyed by it is exceedingly small. It indicates the difference of temperature in any two or more bodies, but gives us no idea of the absolute quantity of caloric in any. In fine, all we learn from the thermometer is, whether one body is hotter or colder than another.

68. All gaseous or æreal bodies as before stated, suffer a much greater expansion by heat than liquids or solids. They also have other peculiarities which in a remarkable manner distinguish them from the latter. In solids and liquids each individual has its own degree of expansion and contraction, whereas all æriform bodies expand and contract alike: consequently if we determine the rate of expansion in one, the rule will apply to every gas now known, or that shall be hereafter discovered.

69. From 32° or the freezing point of water, to 212° the boiling point, gases expand one four hundred and eightieth part of their volume at 32°, for every degree of the thermometer.

70. The art of ventilating rooms and buildings, chiefly depends upon currents as described

68. How does the expansion of gases compare with liquids and solids? And what is the peculiarity of gases?
69. What is the law for the expansion of gases?
70. What is said of ventilation?—What remark of theatres, and other crowded rooms?

under conduction (47). As the heated air of crowded rooms ascends, it is common to have apertures in or near the ceiling for its escape, which is sometimes prevented by a descending current of denser and colder air. These prejudicial effects are counteracted, by heating in some convenient way the tubes or flues intended for the escape of foul air, by which means the cold air if it attempts to descend is heated, and immediately carried upward.

Obs. In theatres the gas or other chandeliers frequently act as heaters, being suspended directly under the flues, the heated air constantly ascends through them, and thus prevents any returning current. But it frequently happens that the flues are too small to transmit all the foul air, hence the galleries and upper parts of crowded rooms are frequently hot and suffocating, from the accumulation of air that cannot pass through the ventilator.

71. From what has been said, it is obvious that our common fires and chimneys are most powerful ventilators, though their good services in this respect are often overlooked. As soon as the fire is lighted, a rapid ascending current of air is established in the chimney, and consequently there must be a constant ingress to supply the demand which generally enters through the crevices of the windows and doors. When these are too small to give the required quantity, the chimney smokes or the fire will not draw, and in such cases it is necessary to make an artificial opening for the admission of air, or sit with a window or door part way open.

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71. What is said of the drawing of common fire-places?

72. I have observed in some of ou studded rooms in this city, heated by m warm air, a difference of 35 degrees b the upper and lower strata of air from th ascent of the heated portions, while those lower parts of the room are confined thei their superior gravity and from the close the apartments: thus we are uncomf warm in the upper, and uncomfortably c the lower parts of the same room.*

73. The system is extremely agreeable tive, and convenient, when properly ma which is seldom the case. The rooms are rally close and oppressive, because, whi heated air is admitted, the rooms are not ciently ventilated to carry off that whic become deteriorated. The apertures by the air is admitted, are generally too smal the air too highly heated; the pipes for co ing the hot air should be large, the quantit siderable, but the temperature should be rate. In this way the disagreeable odour a from the burnt particles of dust is avoide agreeable freshness and temperature kept the air.

72. What is said of high studded rooms?
73. What are the advantages and disadvantages of this m heating rooms?—And how may it be improved?

* These remarks apply particularly to some of our lecture r which the seats are arranged on an inclined plane, where the low are nearly twenty feet below the highest range.

74. *Liquefaction and Congelation.*—By a sufficient degree of heat all solids may be converted into liquids, and all liquids into vapor; and it is highly probable that all liquids and gases by a sufficient degree of cold would be reduced to the solid form.

75. The temperature at which liquefaction takes place is called the *melting* or *fusing point*, and that at which liquids become solid, is called their *congealing* or *freezing point.*

Obs. Thus ice becomes liquid at 32°, lard at 97°, beeswax at 142°, lead at 662°, and platinum at 23177°.

76. All bodies in passing from a solid to a liquid state absorb, or take up a large quantity of caloric. Ice, in being converted to water, absorbs 140° of caloric.

Illust. Let us suppose, for the sake of illustration, that a piece of ice at the temperature of zero (32° below freezing point of water) be brought into a room at the temperature of 40°, and that the ice receives from the room just one degree of caloric every minute: at the end of 32 minutes, therefore, the temperature of the ice will have risen from zero to 32°, where it will remain stationary for 140 minutes, or until the last particle of ice has been melted, when the temperature will again begin to rise at the rate of a degree a minute, and so continue to do until it reach the temperature of the room.

Now, it is evident, that the ice continued to receive from the room one degree of caloric every minute until its temperature had reached that of the room, still there were 140 minutes of

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74. What effects can be produced by a sufficient degree of heat?
75. Define the terms fusing and congealing point.—Describe the congealing point of different substances mentioned in the observation.
76. What is the law when bodies change from solids to liquids, and from liquids to solids?—What is the illustration given?

81. *Vaporization.*—All aeriform substances are generally divided into *gases* and *vapors.*

Vapors are generally distinguished from gases by the facility with which they are reduced to the liquid state, either by pressure or cold; and most of them exist as liquids at the ordinary temperature of the atmosphere: while gases, on the contrary, require generally great cold and pressure to liquefy them; and they never exist as liquids at the ordinary temperature and pressure of the atmosphere.

Illust. Steam is the most obvious example of vapor; the atmosphere, hydrogen, &c., are examples of gases.

82. Nearly all solids and liquids have been reduced to vapor by the application of heat. The facility with which this takes place in many bodies, may be illustrated by exposing to the summer's sun a shallow vessel of water, or a small piece of camphor; each will soon begin to diminish, and if left for any length of time will entirely disappear.

83. Liquids in general are more disposed to evaporate than solids: some of these evaporate at all temperatures, as water, alcohol, and ether; while others, as quicksilver, only evaporate at an elevated temperature.

84. Vaporization may be treated under two heads, *Ebullition* and *Evaporation.*

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81. How are aeriform bodies divided?—How distinguished?—How illustrated?
82 How is vaporization illustrated?
83. How do liquids and solids compare in this respect?
84. How is the subject divided?

85. In ebullition, the rapid escape of vapor through the liquid, in the form of bubbles, produces a violent commotion, generally called boiling, or ebullition; while in evaporation the vapor passes off silently, and from the surface only.

86. The temperature at which ebullition takes place, or in other words the boiling point, varies with the liquid; but where the liquid is the same, the boiling point, under the same circumstances, remains the same; that of ether is 98°, alcohol 176°, water 212°, and mercury 662°.

Obs. The boiling point of water is 212° in a metallic vessel, but in a glass vessel it is 214°.

Exp. If we add a small quantity of iron filings to water that is boiling in a glass vessel, a large quantity of vapor is suddenly given off, and the temperature is reduced from 214° to 212°, where it remains so long as the filings are left in the liquid, nor can it be raised to 214° by additional heat in the open vessel.

87. The boiling point is greatly affected by the pressure of the atmosphere.

Obs. All bodies on the surface of the earth are exposed to a great pressure from the weight of the atmosphere upon them. This weight has been ascertained to be equal to nearly 15 lbs. on every square inch of surface; consequently the pressure upon the body of a middle sized man is more than 30,000 pounds; and that of the atmosphere upon the whole surface of the earth, equal to the weight of a globe of lead 60 miles in diameter.

88. The pressure of the atmosphere is great-

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85. Define ebullition and evaporation.
86. What is said of the temperature required?—What observation on the boiling point of water?—What experiment?
87. How is the boiling point affected?—What observation to illustrate this?
88. Where is the pressure greatest, and how does it affect the boiling point, and what is the practical application?—Give the illustration.

est on a level with the ocean where wate at 212°, and diminishes as we ascend froı height one degree for every 530 feet of a consequently, we are enabled from the l point of water to calculate the height of ı tains.

Illust. Water boils at 187° on the top of Mont Blanc is 25 degrees lower than its boiling point on a level ı ocean. What is the height of this mountain as ca from the boiling point of water?

89. That liquids boil at a lower tempe by removing the pressure of the atmos may be shown by experiment.

Exp. 1. Remove water that is boiling from the fir it under the receiver of an air pump, and remove tl sure by means of the instrument, the water will so mence boiling again, and will continue to boil as we the air from the receiver.

Exp. 2. Ether may be substituted for the hot water the last experiment, and will boil at the ordinary temı by simply removing the pressure of the atmosphere.

Exp. 3. The experiment, called the *culinary parado* trates the influence of diminishe sure in facilitating ebullition.] stop-cock securely into the neck rence flask containing a little boil the water over a lamp for a ı ments, and then suddenly close t cock, and removing the flask pl into a vessel of cold water. Th in the flask, which had ceased to removing it from the lamp, will now commence boiling v

89. How can we show that liquids boil at a lower temperatu moving the pressure?—Describe the experiments.—What is the paradox?—What is the rationale?

—remove it and plunge it into a similar vessel of hot water, it will instantly cease boiling. If instead of the cold water the flask be inverted, and a piece of ice applied to the bulb of the flask, it will also boil violently.

Rationale. In this experiment the air was driven out of the flask by boiling the water, and an atmosphere of steam made to supply its place, which on immersion in cold water was condensed, and a vacuum formed in the flask over the water which boils on the principle already noticed of the pressure being taken off: the vacuum is kept up by the successive condensations of the portions of steam formed, and the boiling continues until the temperature of the water sinks to nearly 72°.

90. All liquids boil at 140° lower temperature when the pressure of the atmosphere is entirely removed than in the open air—that is in a vacuum water boils at 72°, alcohol at 36°, and ether at 44° below zero.

91. If we now reverse the state of things, and increase the pressure on the surface of boiling liquids, we shall in proportion elevate the boiling point.

Exp. This may be illustrated by an experiment with ether; put about a teaspoonful of ether in a small and narrow vial, and holding the thumb firmly over the mouth of the vial, plunge it into a glass vessel such as a common champaign glass, nearly filled with boiling water; the heat communicated will soon be sufficient to boil the ether whenever the thumb is raised, but while the pressure is increased by firmly closing the mouth, the ether will not boil until the temperature has been proportionally elevated.

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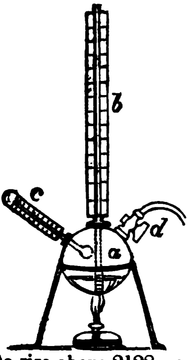
90. What is the difference between the boiling point of liquids in a vacuum and in open air?
91. What effect by increasing the pressure?—What is the experiment to prove it?

92. Although we cannot heat water open vessel above 212°, because all the above that temperature is carried off in yet when the vessel is firmly closed, the is prevented from escaping, and the temp and internal pressure go on increasing, u vessel bursts or the fire is removed.

93. In a sufficiently strong vessel, might be heated to the temperature at other bodies become red hot, without boil



Exp. For experiments of tl the following is a good form of tus, and consists of a hollow globe *a*, a small quantity of qu is poured in, and then the vess half filled with water; *b*, is a b tube open at top and bottom, and ing to the bottom of the globe, through an air-tight collar; *c*, is mometer for indicating the temp *d*, the stop-cock and tube for le the steam; *e*, the spirit lamp. the stop-cock open, heat the glo the lamp till steam issues freely t tube *d*, then close it, and the the ter thus far at 212°, will immedi gin to rise, showing that as soo steam is confined, the temperatur to rise above 212°, and the pressure increases in the sa portion in the globe, as is proved by its forcing the qui up the tube *b*. When the thermometer rises to 250½ the pressure of the steam is twice as great on the insid globe as that of the atmosphere on the outside, that equal to 30 pounds on the square inch. When it rises the pressure will be three times as great as that of the phere, at 294° it will be four times as great.

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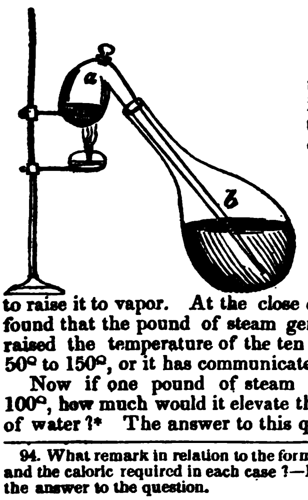
92. How is water affected by confining the steam?
93. How high can water be heated?—What experiment to illus

94. As water freely exposed to the air, cannot be heated above 212°, because the excess of caloric is carried off in the form of steam, it follows that if we can condense this steam to water, by causing a given weight of it to pass into a given weight of cold water, the latter will be heated just as much as the steam is cooled, and by plunging a delicate thermometer into it, we shall ascertain exactly how many degrees have been communicated by condensing the steam.



Exp. Put a pound of pure water at the temperature of 212° into the retort *a*, and let its beak pass into the glass receiver *b*, containing ten pounds of water at the temperture of 50°. Now continue the heat of the lamp at the retort until all the water has disappeared in steam; this will be condensed to water in the receiver *b*, and will yield to the water in *b*, all the caloric which had been required to raise it to vapor. At the close of the experiment it will be found that the pound of steam generated in the retort *a*, has raised the temperature of the ten pounds of water in *b*, from 50° to 150°, or it has communicated to it 100° of caloric.

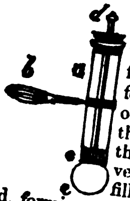
Now if one pound of steam heat 10 pounds of water 100°, how much would it elevate the temperature of one pound of water?* The answer to this question will be the number

94. What remark in relation to the formation and condensation of steam and the caloric required in each case?—Relate the experiment, and give the answer to the question.

* The above and other similar questions will frequently be left without answers, for the purpose of exercising the ingenuity of the pupil, fixing the attention and calling forth the reasoning faculty, all of which it is believed it will have a tendency to accomplish.

of degrees required to change water to vapor, and is *latent heat* of steam. The same remark is applica vapor (at whatever temperature) when converted i It always gives out in the condensation a large amo loric.

95. It was seen in the Exp. (93) that when confined may be made to acquire expansive force as to burst the strongest v It is on account of this property that it is en ed as a moving power in the steam engine construction of which depends on two pr ties of steam, namely, the expansive force municated to it by caloric, and its ready con sion into water by cold. This is illustrated the accompanying figure of an instrument vented by the late Dr. Wollaston.



Exp. It consists of a glass tube *a*, blown a bulb at *e*, and of a piston *c*, which fits the t very accurately, and moves up and down w freedom—*b* the handle. Having previously pu few drops of water into the bulb, heat it careful over a spirit lamp; the steam formed by boilin the water will force up the piston *c* to the top the tube; now plunge the bulb and tube into vessel of cold water, the steam which previously filled the tube and bulb will be suddenly condensed, forming a vacuum, and the piston will descend by the pressure of the atmosphere above it.

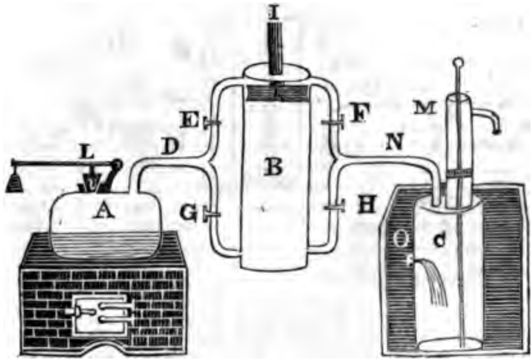
96. Without giving a history of the steam engine, which is a comparatively modern invention, we shall describe this instrument in its present improved form; which differs from the

95. What is said of the useful application of steam?—How is it illustrated by experiment?
96. What is the difference between the above model and the engines now in use?

above simple model, chiefly in the manner of condensing the steam. In the model, the steam is condensed in the same vessel where it is generated; while in the steam engines now in use, it is condensed in a separate vessel, surrounded by cold water, and called the *condenser*.

97. In a common low pressure steam engine, there are three principal parts, the *boiler*, the *cylinder*, and the *condenser;* in the first the steam is formed, in the second it is worked, or in other words raises and depresses the piston, and in the third it is condensed to water.

Illust. The following is perhaps the most simple illustration of the principles of the steam engine, in which Fig. 1.



General Description.

A, represents the boiler where the steam is generated

97. Describe the principles of the low pressure engine.—Give the general description from the first figure.—Give the particular description.—What is the use and application of the safety valve?

and passes up the tube *D*, towards the cylinder *B*, ters by the tube *E*, or *G*, (according as it is to pass low the piston *K*;) it then passes out through the *H*, and thence through the *eduction* pipe *N*, into *C* condensed.

Particular Description.

Fig. 1. The boiler *A*, and tube *D*, are filled with four stop-cocks *E*, *F*, *G*, and *H*, are closed, and the is filled with air. We open at the same instant th *E* and *H*, the steam rushes through *E* into the cy pressing upon the piston *K*, forces it to the bottom der, and at the same instant forces the air, which w the cylinder, through *H* and *N*, into the condenser it is withdrawn by means of the air-pump *M*, wh stantly in operation, and pumps out both the air an that has been condensed.

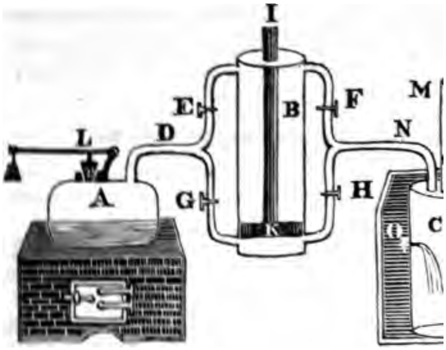


Fig. 2. The piston *K* is now at the bottom of t *B*, the upper part of which is filled with steam, and are open; we now close *E* and *H*, and at the same in *G* and *F*. The steam rushing through *G* into the the cylinder forces the piston *K* to the top again; same time the steam, previously in the upper part of der, rushes out through *F* into the condenser *C*. T ternately opening and closing the stop-cocks on each cylinder, the piston is moved up and down with grea

The boiler is supplied with a safety valve, kept down by the lever L and its accompanying weight; and if the steam in the boiler should increase in quantity before the pressure becomes so great as to endanger bursting, it will by its own power raise the valve v, when the superabundant steam will escape. The stop-cocks which were formerly worked by hand, are now turned by the engine itself. O is a stop-cock for supplying the condenser with a small jet of cold water to assist in condensing the steam.

98. There are two kinds of steam engines in general use; the *high pressure* and *low pressure*. The former has no condenser, the latter has. The engine just now described is the low pressure engine; to change this to high pressure, we have only to separate the condenser at N, where the steam, instead of going into the condenser, would pass out into the atmosphere in successive jets.

Obs. In all high pressure engines, such as are generally used to move machinery attached to manufactories in our cities or elsewhere, the steam is seen passing out of a pipe or chimney in successive jets, or puffs in white vapor; wherever these jets are seen, that fact alone is sufficient evidence that it is a high pressure engine. The steam-boats that run on the Mississippi are generally high pressure; while those that run from New-York to Albany, from New-York to Philadelphia, and from New-York to Providence, are low pressure boats.

99. Low pressure engines require much more room than high pressure, hence the latter are generally used where it is particularly requisite to save room: on this account they are always used to propel the locomotives on rail-roads.

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98. What is the difference between the high and low pressure engine?—What observation to illustrate this subject?

99. Under what circumstances should low pressure engines be used, and why?—What remark of rail-road locomotives?

Obs. All who have travelled by rail-roads mu ed the noise produced by the rapid successive je the steam-pipe of the locomotive.

100. *Evaporation*. Evaporation ebullition, consists in the formation of vapor. The difference between the that the former takes place quietly, wh ter exhibits the appearance of boiling.

101. Evaporation takes place at all temperatures; thus, a shallow vessel exposed to the atmosphere for a few summer will entirely disappear; a simila of spirits of wine would require much le to evaporate, while one of ether would disa in a few minutes. The more volatile the l the more rapid will be its evaporation unde same circumstances. Some solids also ev rate at ordinary temperatures, as camphor, w quicksilver does not begin to rise in vapor u heated to about 70° or 80°.

102. Evaporation, according to Dr. Turn is affected by the five following circumstance the extent of surface in the liquid, its tempera ture, the state of the atmosphere in regard to dryness and moisture, currents of air, and the pressure of the atmosphere.

103. 1st. *Extent of surface*. It is evident, since evaporation only takes place at the sur-

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100. What is the difference between evaporation and ebullition?
101. What examples illustrate evaporation?
102. What are the circumstances which affect evaporation?
103. What is said of the extent of surface?

face, that the more surface exposed, the greater will be the quantity evaporated.

Exp. Put an equal quantity of ether in a shallow and in a deep vessel, so that the former shall expose twice the surface that the latter does, the former will have entirely evaporated, while the latter contains one half its original quantity.

104. 2d. *Temperature.* The effect of heat may easily be illustrated by putting equal quantities of water into two saucers, and placing one in a warm and the other in a cold situation. The former will be quite dry, while the latter has scarcely suffered an appreciable diminution. Liquids evaporate much more rapidly in summer than in winter.

105. 3d. *Dryness and Moisture.* When the air is dry the evaporation is very rapid, even though it be quite cold. Thus, in dry cold days in winter, the evaporation goes on rapidly, while in damp weather, when the air is saturated with moisture, though it be quite warm, the evaporation is comparatively trifling.

Illust. In warm weather we perspire freely, and when the air is clear and dry the perspiration is carried off as fast as formed, cooling the body and producing an agreeable sensation; allowing the temperature to be the same, but instead of a clear atmosphere it be charged with vapor, we perspire as freely as before, but the atmosphere being already charged with moisture cannot carry it off, it therefore remains on the surface, producing a disagreeable sensation of oppression. It is this circumstance which renders those sultry days, common during the month of August, so oppressively hot.

106. 4th. *Currents of Air.* Evaporation is

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104. What of temperature?
105. What of dryness and moisture?—How illustrated?
106. What of currents of air?

much slower in still air than in a curre the reason is obvious. During the eva the air immediately above the liquid, main stationary, becomes saturated wit ture, when no more can be taken up current of air, moving over the liquid, co ly carries away the vapor as fast as it ris brings in contact a fresh stratum of dry a thus the evaporation is kept up without ruption.

107. 5th. *Pressure.* The remarkable ence of pressure in the formation of vapor shown in the subject of ebullition, (79, Ex 2, and 3,) where water was made to boil n degrees below 212°, and ether at the ordi temperature, by merely removing the pres of the atmosphere.

108. It was before shown (94) that wate being converted to steam, absorbs about 1 degrees of caloric ; and as the same law ap to the evaporation of water at all ordinary peratures, in this latter case ; also, every o of water that is carried off from the earth in form of vapor, robs the earth of as much ca as would raise the temperature of an ounc water about 1000 degrees. To render the ject still more plain, the caloric carried o one ounce of vapor, would be sufficient to

107. What of the pressure of the atmosphere?
108. What is said of the evaporation of water at ordinary temper and how illustrated ?—What is the corollary ?—How does the wind the temperature?—What is the first explanation with ether ?—What second ?—What observation on cooling apartments in India ?

seven ounces of water from the temperature of 60° (which is the ordinary temperature of water as drawn from our wells) to the boiling point.

Corollary. Hence evaporation is in all cases a cooling process, and by causing rapid evaporation at common or low temperatures, we have it in our power to produce considerable degrees of cold.

Illust. Thus if a wet cloth is spread out in a keen wind at a temperature a little above freezing, the water by rapid evaporation soon carries off caloric enough to reduce that which remains below the freezing point, making the cloth hard and stiff by the formation of ice within its pores.

Exp. 1. To prove that cold is the result of rapid evaporation, nothing more is necessary than to pour a few drops of ether upon the hand, the ether will soon disappear, leaving a keen sensation of cold.

Exp. 2. We can vary the experiment by covering the bulb of a common thermometer with a little lint, or a fold of gauze, and dropping a little ether upon it, the degree of cold produced will be marked by the descent of the mercury in the tube. If we substitute for the thermometer a thin glass tube, containing a small quantity of water at 60°, and hold it in the draught of a window to assist the evaporation, if the temperature of the air be not much above 40°, a little dexterous management will enable the experimenter to freeze the water in the tube.

Obs. Apartments in India are often separated from their courts by curtains instead of walls; and these curtains, in order to cool the air in the rooms, are continually sprinkled with water, the rapid evaporation of which reduces the temperature of the rooms 15° or 20°.

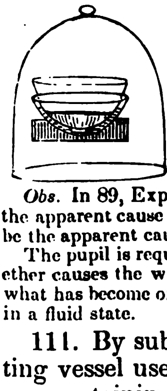
109. The ancients supposed that the equatorial regions must be uninhabited, from the intensity of the heat; not knowing the fact, that evaporation always increases with the intensity of the heat, and the vapor so formed ascends and carries off the heat in a latent state. When

109. What remark respecting the opinion of the ancients, and how is the heat of equatorial climates disposed of?

cooled in the upper regions of the atmosphere, or wafted to colder climes, it is condensed, and, in the form of sensible heat, gives out the caloric which it had absorbed. Thus the vapor becomes the transporter of heat from the torrid to the frigid zones.

110. Availing ourselves of the principle of evaporation, we can freeze water by means of ether under the receiver of an air-pump.

Exp. Provide two very thin watch-glasses, or what is equally as good if not better, cut off the bottoms of two florence flasks in the form of a watch-glass, (as directed in Appendix 1.) Place one within the other, and in the inner vessel pour a little ether, and in the outer one a little water, and place the two on the plate of the air-pump, as seen in the figure, and cover the whole with the receiver. Now exhaust the receiver, the ether will soon commence boiling, and in a short time the water contained in the outer vessel will be found frozen.



Obs. In 89, Exp. 3, it was seen that ice or cold water was the apparent cause of boiling; but in this case boiling seems to be the apparent cause of the formation of ice.

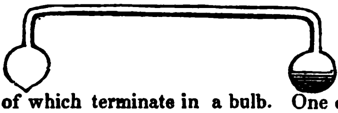
The pupil is requested here to explain how the boiling of the ether causes the water to freeze; or, in other words, to state what has become of the caloric which before retained the water in a fluid state.

111. By substituting for the double evaporating vessel used in the last experiment, a single one containing a little water, and placing under the same receiver a vessel of oil of vitriol to absorb the vapor as fast as given off, we can freeze water by its own evaporation. But the

110. How can water be frozen under the air-pump receiver?
111. What experiment was with oil of vitriol?

time required to perform the experiment, its uncertainty unless the room be comparatively cold and the air pump in superior order, render it inexpedient to attempt the experiment without considerable facilities for accomplishing it; and besides,

112. The same method of freezing water by its own evaporation is illustrated in a more simple manner by the *cryophorus* or *frostbearer* of Dr. Wollaston.



Illust. It consists of a glass tube bent twice at right angles, one bend being near each end, both of which terminate in a bulb. One of the bulbs is half filled with water, and the interior of the tube is perfectly exhausted of its air, the consequence of which is that the water in the instrument is greatly disposed to evaporate; but the process cannot proceed far in consequence of the whole instrument being filled with vapor which presses upon the surface of the liquid and thus checks the operation.

Exp. In order to get rid of the vapor as fast as formed, and to induce the formation of more, the empty ball *a* is plunged into a freezing mixture, as represented in the accompanying figure, which continually condenses the vapor within, and thus accelerates the evaporation from the ball *b*, until the water within it is robbed of so much of its caloric that it is at length frozen.

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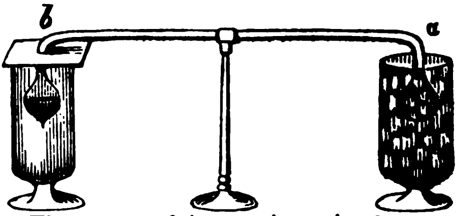
112. What was the name of Dr. Wallaston's instrument?—Describe it.—Describe the experiment with it.—What is necessary to the success of the experiment?



Obs. The success of the experiment is often frustrat when attempted in a warm room, by the deposition of vapor its condensation on the ball *b*. The contact is prevented, enclosing the ball in a glass vessel supplied with a cover as presented above.

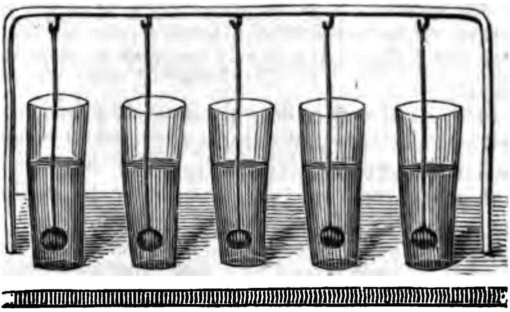
Query. The pupil is desired to state the reason why deposition of vapor on the bulb *b*, should prevent the wa within from freezing? The proper answer may be obtai from the illustrations of paragraph (94.)

113. There are many cases in which we sort to the principle of evaporation to produ cold at common temperatures. The sprinkli of floors and pavements with water tends to co them, and the air which is about them. *Wi coolers* are porous earthen vessels, which are d ped into water, and by exposure to air the wa evaporates and thus cools the vessel. In so hot climates, as in the West Indies, porous eart ern bottles are filled with water and suspend in a current of air, the water oozes to the su face, whence it is rapidly removed by evapor tion, and cold is produced.

Give the answer to the query.
113. What instances of practical application are mentioned?

SPECIFIC CALORIC.

114. Equal weights of the same body at the *same* temperature, contain equal quantities of caloric; but equal weights of *different* bodies at the same temperature, contain unequal quantities of caloric.



Exp. Take five balls of metal, each weighing exactly half a pound, two of iron, one of copper, one of tin, and one of lead. Suspend them by threads in boiling water, and each will be heated to 212°. Now remove them and quickly plunge them into separate tumblers of cold water. As the quantity of water and the temperature in each tumbler is the same, we should naturally suppose that each of the balls would communicate the same amount of caloric to the water; and hence that a thermometer immersed in each vessel would indicate the same temperature; but the fact is far otherwise, and except in the case of the iron balls, each communicates a different temperature to

114. What is said of the quantity of caloric in the same and different bodies?—Describe the experiment.—What is said of the quantity of caloric communicated to the respective tumblers?

the water, the iron, the highest, the copper not quite the tin less, and the lead the least of all.

The quantity of caloric which each of the metal above experiment communicates to its respective tu water, is called its *specific caloric*. The two iron ball the water equally, prove the first part of the above pro and the other three prove the second part.

115. If in cooling from a given tempe equal weights of different bodies give ou ferent quantities of caloric, these same b would require different quantities of calor heat them through a given number of deg Hence,

116. By the specific caloric of any body, mean the quantity of caloric required to ele its temperature a given number of degrees that given out by the same body in coo through the same number of degrees.

Obs. Calling the specific caloric of water 100°; that of oil will be 50°; quicksilver, 4.347°; hence, quicksilver con twenty-three times les specific caloric than water.

SOURCES OF CALORIC.

117. The sources of caloric are chiefly f 1. The sun; 2, Electricity; 3, The bodie living animals; 4, Mechanical action; 5, C mical action.

118. That a vast amount of caloric is c

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115. If equal weights of different bodies in cooling give out dif quantities of caloric, what inference is drawn?

116. What is meant by specific caloric?—What observation to illu this?

117. What are the sources of caloric?

municated from the sun, is too evident to require any illustration, and electricity and animal heat as sources of caloric will be explained in other parts of the work.

119. *Mechanical action* is a fruitful source of heat, and includes *percussion*, *friction* and *condensation*.

120. By *percussion*, flint and steel are struck together, producing heat enough to set fire to tinder. The sparks which are elicited are nothing more than small particles of steel, which are separated and heated sufficiently by the collision to set them on fire, and cause them to burn as they pass through the air.

121. By *friction* of two pieces of dry wood, savages frequently obtain sufficient heat to kindle fires. Machinery is frequently set on fire by the heat produced from the friction of its different parts. The friction of a carriage wheel against its axletree has been known to set fire to the latter, and I have more than once seen the rail-way on which a ship is launched fired by the friction of the bottom of a vessel in passing over it. Sir H. Davy succeeded in melting two pieces of ice, by rubbing them together in an atmosphere far below the freezing point of water. The common method of rubbing the hands in a cold day for the purpose of warming them, is familiar to every one.

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119. What is said of mechanical action ?
120. Illustrate the remark on percussion.
121. What is said of friction, as a source of heat ?

122. *Condensation* is also a fruitful sc
of caloric. Whenever the particles of w
bodies are composed are brought neare:
gether, they always give out caloric. Thus a
of iron has been heated to redness by vigo
hammering in consequence of the condensa
of its particles.

Exp. In the following experiment, illustrated by
accompanying wood cut, common air is so much cond
as to give out a sufficient quantity of caloric to set f
tinder. This instrument, which is called a *conde*
syringe, or more commonly a *fire pump*, contains i
lower part of its piston, a small hole for the pur
putting in a small quantity of tinder, and by sudden
cing the piston to the farthest extremity of the barr
air contained is so much condensed as to give out c
enough to set fire to the tinder.

123. *Chemical action* is the most fruitf
all artificial sources of heat; every specie
combustion is included under this head
well as all the cases of heat produced by var
mixtures.

Exp. 1. Mix two parts of chlorate of potash with
parts of loaf sugar in powder, and pour upon the mixt
few drops of sulphuric acid; the chemical action of the
terials upon each other will be sufficient to ignite the sug

2. Mix in a cup made of the bottom of a florence flask
off with a heated ring as directed in appendix) (2.) two
sures of sulphuric acid with one of water, both having be
the temperature of 60°, heat enough will be developed to
the temperature of the mixture to about three hundred de
from the condensation.

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122. What of condensation?—Describe the experiment.
123. What is said of chemical action?—What experiment with ch
of potash and sugar?—What experiment with oil of vitriol and wat

LIGHT.

124. Light in many of its properties very closely resembles caloric; both are emitted in the form of rays, and pass in straight lines through the air; both are subject to the same laws of reflexion. Very intense heat is always accompanied with light, and it is very probable there is no case of intense light unaccompanied with sensible heat. So nearly allied indeed are the two principles, that the one seems convertible into the other, and hence it has been supposed that they are merely modifications of the same subtile agent.

125. There are two kinds of light, *natural* and *artificial*. The first proceeds from the sun and stars; and the second from various terrestrial sources.

126. Rays of light pass freely through some bodies, which are hence called *transparent*, such as glass, rock-crystal, and water; while those bodies that entirely intercept it are called *opaque*.

127. All the rays of light that fall obliquely upon transparent bodies are refracted, or bent out of their course.

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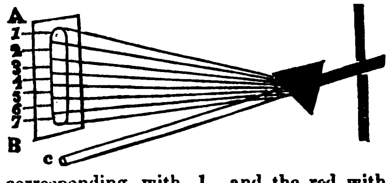
124. What is the resemblance between light and heat?
125. What is said of natural and artificial light?
126. What are *transparent* and *opaque* as applicable here?
127. What is said of refracted rays?—What is remarked of Newton?—Describe the experiment with the prism.

Obs. It was this property, namely, refraction, that enabled Sir Isaac Newton to discover the compound nature of the solar light, by causing it to pass through a triangular piece of glass, called the *prism*, the action of which depends upon the different refrangibility of the seven different rays. Beginning with the first, or most refrangible, the succession is *violet*, *indigo*, *blue*, *green*, *yellow*, *orange*, *red*.

The decomposition of light only requires that a ray should be admitted through a small aperture into a room, and made to pass through a triangular prism, as represented by the figure.



The direction of the ray towards the point *c* will be changed by refraction, and at the same time it will be decomposed into the colors already named; the violet corresponding with 1, and the red with 7. The colored figure, formed by the spreading out of these different rays, as represented between A and B, is called the *prismatic spectrum*, always bounded by the violet ray on the one side, and the red on the other.

128. The seven colors of the spectrum are divided into three kinds, from the three different effects produced by them; the *calorific* or heating rays; the *luminous*, and the *chemical* rays.

129. The *calorific* rays are generally described as in the red ray, or a little below it; but different experimenters have placed it differently, some making it a little beyond the red, others in the red, orange, or yellow; but all these discrepancies have lately been reconciled, by discovering that the place of greatest heat depends

128. How are the seven colors divided, and why?
129. Where is the greatest heat, and why have experimenters differed on this point?

entirely on the kind of prism used. If it be of common flint glass, it will be in the red, or a little below it; if it be a hollow prism filled with water, the greatest heat will be in the yellow; if it be the same prism filled with sulphuric acid, it will be found in the orange.

130. The greatest *illuminating* power is found to be in the yellow ray, and diminishes as we proceed from this point to either end of the spectrum.

Obs. The illuminating power is found by letting the spectrum fall on a large printed sheet, when the letters that are reflected in the yellow rays can be seen more distinctly than those in any other color.

131. It has long been known that the solar rays are capable of blackening a stick of lunar caustic (nitrate of silver). This effect takes place very slowly in the diffuse light of day, but in less than a minute in the direct rays of the sun. The degree of chemical action, produced by the different rays, was ascertained by spreading a solution of the nitrate of silver on a sheet of white paper, and exposing the paper in the prismatic spectrum. In a very few seconds that part of the paper exposed to the violet ray was changed to a deep violet color, the indigo required a little longer time, the blue still longer, and the green the longest of all; no perceptible change being produced beyond the green rays.

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130. Where is the greatest illuminating power, and how is it found?
131. What experiment is described with lunar caustic, and where is the effect greatest?—What observation on *indelible ink*?

The maximum effect was found a little beyond the violet rays of the spectrum.

Obs. The common article called *indelible ink*, used for marking on linen, is nothing more than the nitrate of silver, a salt composed of silver dissolved in aquafortis; this when exposed to the sun's rays, and still more rapidly in the violet rays of the spectrum, is decomposed, the silver being deposited in the texture of the cloth in the form of a black powder, while the aquafortis is in part evaporated, and the rest is removed by the first washing.

132. It was stated (127) that light is refracted by passing obliquely out of one medium into another. If the ray is allowed to pass through certain mineral substances, such as transparent calcareous spar, it will exhibit a double image of any object seen through it. This property is called *double refraction.*

Illust. Thus placing a crystal of this mineral in a certain position, upon a clear piece of paper, having a single black line drawn upon it, when seen through the crystal, the line appears double. In this case the light which proceeds from the object in coming through the mineral is split into two parts, one of which is bent out of its course more than the other, which causes the object to appear double.

133. The second kind of light, is that which proceeds from substances strongly heated, and is of terrestrial origin, and consequently called artificial, in contradistinction to natural light.

134. All bodies when intensely heated emit light; this appearance is called *incandescence*, and begins to appear in solids at the temperature

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132. What is meant by double refraction?—Give the illustration.
133. What is said of artificial light?
134. What is said of incandescence?

of about 700° in the dark, but in broad day-light at about 1000°.

135. The different degrees of light and heat given off are described under the terms obscure red, bright red, yellow, white heat, &c.

136. Nearly all artificial lights are produced by the combustion or burning of inflammable matter.

137. Light is absorbed by some bodies, and afterwards emitted at common temperatures, or in which the heat is not in proportion to the light, giving rise to an appearance called *phosphorescence.* The substances producing these effects are called *phosphori.*

138. Phosphori are of three kinds: *solar* phosphori, phosphori *from heat,* and *spontaneous* phosphori.

139. *Solar phosphori* are those substances which by exposure to the sun's rays absorb a part of the light, which they emit again on being carried into a dark room. Such are the diamond, borax, boracic acid, and snow.

Obs. Du Fay exposed a diamond to the sun's rays, and immediately covered it with black sealing-wax, and on the removal of the wax several months afterwards in a dark room, sufficient light was emitted to distinguish the figures on the dial of a watch. Objects which are seen indistinctly in a cloudy night, are rendered more clear and distinct when the ground is covered with snow, in consequence of the light which it emits.

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135. What are the different terms used?
136. How are artificial lights generally produced?
137. What is phosphorescence, and what are phosphori?
138. How many kinds of phosphori?
139. Describe solar phosphori.—What was Du Fay's experiment?

140. Phosphori by heat, are those which are rendered phosphorescent by heat alone; such as the mineral called *fluor spar*, or more commonly *Derbyshire spar*. The yolk of an egg when dried, becomes luminous by heat; also spermaceti, wax, and tallow.

Exp. Heat a common fire shovel or iron plate nearly to redness, and then sprinkle on it some fluor spar, it will immediately give out a beautiful green light.

141. Of *Spontaneous Phosphori*. The firefly and glow-worm are remarkable instances. The luminous appearance of the sea, as seen in the wake of vessels and steam-boats, is ascribed to the presence of exceedingly minute animals. This explanation is rendered probable from the fact, that the water when allowed to filter through fine paper, which would retain the animalculæ, loses the property of becoming phosphorescent.

142. All plants that grow in the light are colored, while those deprived of it are white. Thus celery is rendered white, by cultivating it protected from the light; the young shoots of potatoes that frequently grow in dark cellars, are white and nearly tasteless.

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140. What are phosphori by heat?—Describe the experiment with the Derbyshire spar.
141. What is said of spontaneous phosphori?
142. What effect has light on plants?

ELECTRICITY.

'his subject will be treated under the follow-
heads:

Common Electricity.
Galvanic Electricity.
Magnetic Electricity.

COMMON ELECTRICITY.

43. ELECTRICITY is comparatively a mo-
ı science. The ancients, it is true, were ac-
inted with a few detached facts; they knew,
example, that amber (called in Greek elec-
) had the power of attracting and repelling
t bodies after it had been rubbed in contact
ı a piece of woollen or silk. The amber,
onsequence of this remarkable property, was
ed an *electric*, and the phenomena presented
t were together called *electricity*. Afterwards
ɜr substances having properties similar to
ɔer were discovered, among which are glass,
n, sulphur, sealing-wax, &c., all of which

What knowledge had the ancients of electricity?—What is said of
?—What is said of electrics and non-electrics?

were denominated *electrics*, and all those whic could not be excited were called *non-electrics.*

144. Electricity is supposed to be a subtil fluid, somewhat like caloric in its nature; th earth, and every body with which we are ac quainted, contains a certain portion of it, whic exists only on the surface, and in a latent o concealed state, so that we are not aware of it presence until we take some means of arousin or exciting it.

145. Thus, if a glass tube be rubbed i contact with a silk handkerchief, it will at tract light substances when brought near, suc as small fragments of paper, cotton, gold leaf &c., and if the knuckle be brought near the tub while in this state, a small spark will pass fro the tube to the hand, accompanied with a snap ping noise, and a sensation like the prick of a pin.

Exp. Suspend a light feather by a piece of fine thread, an having excited the glass tube by means of silk, present it to th feather, which will be attracted, but on gently withdrawing an again bringing it near the feather, the latter will be steadily re pelled, so that it will be impossible to approach it with th tube; after a while, however, it loses its repulsive power, an is again attracted and then repelled as before; these two stat may be understood by inspecting the accompanying wood cut

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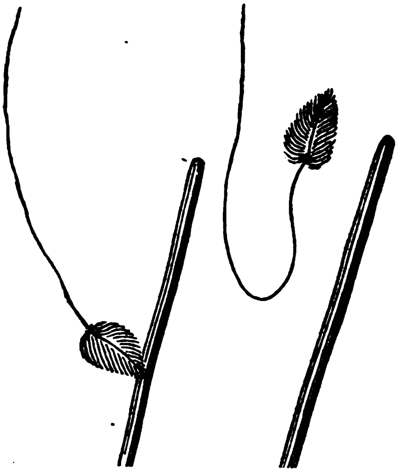
144. Define electricity.
145. Define the experiments.



146. It would be interesting to inquire, what kes place when we rub a piece of glass with a lk handkerchief? According to Dr. Franklin, ie silk and glass, before being rubbed, contain-l an equal share of the electric fluid, which was niformly spread over the surface; but when the vo were rubbed in contact, the silk was robbed : a part of its electricity by the glass; hence ie former have less than its natural share, and ie latter more; if, therefore, we present to the ass any body that has not been excited, it will ceive from it its excess of electricity in the

.46. Give the rationale according to Franklin's theory.

form of a spark, as proved by presenting the knuckle to the excited tube. But the silk may be made to exhibit the spark also after friction, by presenting it to an unexcited body; here, however, the spark passes from the body to the silk, because the latter being robbed of its fluid by the glass, has really less than it had at first, and will take it from any body that has its full natural share.

147. From the above remarks, it appears that electricity has a tendency to diffuse itself uniformly over the surfaces of all bodies. This is called its tendency to an equilibrium; and all electrical experiments are nothing more than the different methods of disturbing this equilibrium, or in other words, robbing one body of its electrity to give it to another.

148. Excite the glass tube as in *Exp.* (145) and cause it to repel the feather, while in this state, rub a stick of sealing wax, or roll of sulphur, in contact with flannel or woollen cloth, and present it to the feather, it will be attracted and fly to it.

149. Now reverse the experiment, and having electrified the feather by the sealing wax, bring the excited glass near it, and instead of being repelled, it will be attracted.

150. These experiments show that the electricity excited in the glass, differs from that ex-

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147. What is the tendency of electricity?
148, and 149. Describe the experiments 149 and 149.
150. What do they prove?

cited in the sealing-wax, inasmuch as bodies repelled by the former are attracted by the latter; and *vice versa*.

151. Hence bodies having the same kind of electricity, as was before shown (145), repel each other, while those having different kinds, attract each other.

152. Du Fay, a French electrician, explained the above facts, by supposing there were two distinct electric fluids, one naturally belonging to the sealing-wax, resin, and all resinous bodies, and the other belonging to glass, and all vitrified or glassy bodies; the former was accordingly called *resinous* electricity, and the latter *vitreous*: but the terms *negative* and *positive* are more generally used at the present time; the former corresponds to the resinous, and the latter to the vitreous. The feather electrified by the excited *glass*, is said to be in a *positive state*, while that by the *sealing-wax*, is *negative*.

153. If the glass when rubbed by the silk be positive, by robbing the silk of a portion of its electricity, the silk is necessarily rendered deficient or negative; hence we have developed another electrical law, which is, "that one kind of electricity cannot be produced without the other," and that when the body becomes positive, some part of the exciting arrangement must be as highly negative.

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151. What is the inference from these experiments?
152. How did Du Fay explain them?
153. What law is developed by rubbing glass and silk?—Give the illustration.

160. Any body is said to be *insulated* when placed in such a situation as to be surrounded by non-conductors. Thus, the metallic bar in the experiment last described, which is in contact with nothing but silk and dry air, both non-conductors, is said to be insulated. A person may be insulated by standing on a stool supported glass legs.

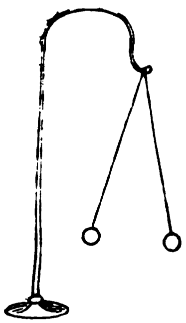
ELECTRICITY BY INDUCTION.

161. It was shown (151) that whenever electrical attraction exists between any two bodies, those bodies must be in opposite electrical states; thus, in Experiment 2d (145), the feather before it was approached by the glass tube was in its natural state, and indicated no signs of electricity whatever; but the moment an excited glass tube was presented, the feather was thrown into the opposite electrieal state from that of the glass, merely by the approach of the glass. The feather is said in this case to be electrified by induction, or in other words, the excited glass coming near, excites in the feather an opposite electric state.

Obs. Electricity by induction is always produced when an excited body is brought near another body unexcited. The same effect is produced if one side of a non-conductor receive one kind of electricity; the opposite side is thrown into the opposite state by induction. This will be further explained under the Leyden Jar.

160. What is understood by insulation ?
161. What is meant by electricity by induction ?—What observation illustrates the subject?

ELECTROMETERS.

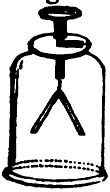


162. An electrometer is an instrument used for showing when a body is electrically excited. It is made in a variety of shapes, one of the most common is that represented in the accompanying wood cut, in which a glass rod bent in the proper form and inserted into a wooden base, supported a couple of pith balls which are suspended by delicate threads of white silk. When an excited body is presented, the balls will first be attracted; but acquiring the same degree of electricity as the excited body, they will soon be repelled as seen in the figure.

163. One of the most useful, most simple, and most easily made, is constructed by suspending two very light and downy feathers, by two threads of raw silk, from the ceiling or some other convenient place. The threads should be at least four feet in length, and when unexcited will hang together, but on approaching them with an excited glass tube, they will first be attracted, but both acquiring the same kind of electricity, they are soon repelled.

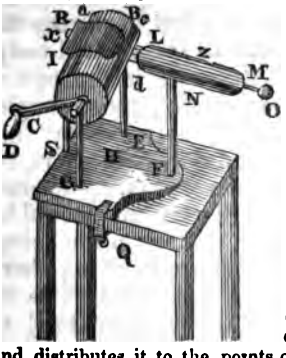
164. For still more delicate purposes, the

162. Define electrometers.
163. Describe the most simple construction.
164. Describe Bennet's electrometer.

gold leaf electrometer of Bennet is subst
it is generally enclosed in a glass jar, a

sists of a brass cap and a con
wire, which passes through th
and terminates in two strips
leaf; as seen in the accompa
figure. I have seen the gold
diverge, by bringing an excite
tube within five or six feet
brass cap.

Electrical Machines.

165. The electrical machine, is mad
variety of forms, but there are two kinds i
ral use, the *cylinder* and *plate* machines



Illust. The figu
sents a cylinder ma
which B is the glass
supported on glass
and E. I R, the rul
a loose flap of silk c
over the cylinder
crank, with its han
M, the prime condu
or brass supported
glass pillar N, havin
in the extremity L f
ing the electric fluid
glass cylinder. On
the machine, the gla
der receives all the
electricity from the
and distributes it to the points on the prime condu
rubber by this means becomes deficient or negative,
prime couductor is positive, or in excess. If the han

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165. What is said of electriical machines?—Describe the cy
chine.

sented to the conductor in an excited state, a spark will pass to the hand; and if the hand approach the rubber, instead of the conductor, a spark will also pass, but in an opposite direction, because the rubber in this case has less than its natural share, and the hand when compared with it has more, or is in a positive state, and will impart a portion of its own electricity, in the form of a spark to make up the deficiency.

166. The plate electrical machine, consists of a flat plate of glass of the kind used in making looking glasses: it is cut into a circular form, a hole is made through its centre, and an axis passed through it. It is then mounted on wooden pillars or frame work, with the axis horizontal, as in a common grind-stone.—The rubbers are fitted on each side of the plate, and the prime conductor near its circumference; and the latter is used in the same manner as the cylinder machine.

167. To put the electrical machine in good order, every part must be dry and clean, because dust or moisture would, by its conducting power, diffuse the electric fluid as fast as accumulated. To increase the effect, an amalgam made by mixing one part of metallic antimony in a melted state, with two of quicksilver, heated nearly to the boiling point—and making them into a stiff ointment with lard or tallow,—the rubber is covered with this amalgam.

168. Both the cylinder and plate machines are in general use; but for ordinary purposes, the

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167. To put a machine in order, what is requisite?—What is used to increase the effect, and how is it prepared?
168. Which kind of machine is preferable, and why?

former is preferable: as it is more simple in its construciion, and more easily managed.

169. By means of attraction and repulsion, a great variety of elegant and amusing experiments may be made with the electrical machine. Among the most striking of these is the head of hair, which stands on end when excited, in consequence of the repulsion of the similarly electrified hairs. A similar experiment is made, by placing a person upon the insulating stool, in connexion with the prime conductor of the machine, as seen in the figure.

170. The electric bells, the pantomime dance the electric fly-wheel, the electric orrery, luminous words, &c., are all highly interesting and amusing experiments.

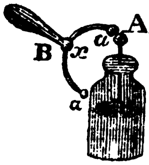
171. The Leyden jar from its extensive use in electrical experiments, and the amusement and instruction it affords, merits a particular description. The application and uses of this instrument, like many other valuable discoveries was the result of accident.

When the subject of electricity had acquired considerable notice in Europe, an association of scientific gentlemen at Leyden, were amusing

169. What experiment is particularly mentioned?
171. How was the Leyden jar discovered?—What kind of jars were first in use?—What was at length substituted?

themselves with electrical experiments, during which, it occurred to one of them, to charge a tumbler of water with electricity, and learn by experiment, whether it would affect the taste. Having directed a current of electric fluid for some time into the water, he grasped the tumbler and brought it to his lips, but before he could taste the water, he received the full charge of electricity in the extremity of his nose, which happened to be very prominent. Consternation seized the whole company, and various exaggerated reports were spread throughout the country of the wonderful discovery and tremendous effects of the electric shock. Jars of water were at first used, but it was at length proposed to use some substance that was a better conductor; and the jars were partly filled with metallic filings. Subsequently, however, tinfoil was substituted for the metal filings, and this arrangement is is now in general use.

172. The Leyden jar is generally made by coating externally and internally, a wide mouthed glass jar, with a wire passing through its cap and extending to the bottom. The top of the wire is surmounted by the brass ball A, as seen in the wood cut.



172. How are the Leyden jars generally made ?

173. To charge the jar, nothing more is necessary than to present the brass ball A, to the prime conductor of the electrical machine, while the latter is in action. The outside of the jar is generally either in connection with the earth by means of a chain, or with the rubber.

In order to discharge the jar, we use a discharger as represented by B, in the wood cut, in which *a*, *x*, *a*, represent the wire and knobs, and B the glass handle. The discharge is made by presenting one of the knobs *a*, to the outside coating, and the other to the brass ball A, as in the position represented in the wood cut above.

Obs. It is generally stated in the books, that in order to charge the jar successfully, the outer coating should communicate by means of a chain, or some metallic conductor with the earth; but it is much better to have the outer coating, by means of a chain, in connexion with the rubber: by which means the outer surface will become highly negative, while the inner one becomes highly positive.

174. If, when we have charged the jar, we hold the exterior coating in one hand, and touch the knob with the other, the spark passes as before, and we perceive a peculiar, and in some cases painful sensation at the wristand elbows and across the breast, called the *electric shock*. Any number of persons can receive the shock at the same time, by forming themselves in a circle communicating with each other, and letting the

173. How is it charged, and how discharged?—What remark is made with regard to connecting the outer coating with the earth?

174. What is said of the electric shock, and the number that can receive it at the same time, and how is it accomplished?—Through what space has it been passed, and what is said of it?

first touch the outer coating of the jar, and while his hand rests in contact, let the last one bring his finger to touch the knob, every person in the connection will feel the shock at the same instant.

Obs. The shock has been made to traverse a distance of four miles, without perceptible lapse of time; hence the motion of the electric fluid must be incalculably rapid.

175 It is natural to suppose, since we are compelled to coat the jar in order to charge it successfully, that the electricity resides in the coating; but it can be proved to reside in the glass only, for the coatings may be rendered movable, and thus we can analyze the jar.

Exp. To a common quart tumbler, of the shape represented in the figure, fit an inside and outside coating of common tin plate, so that the glass shall project considerably above the coatings. To the bottom of the inner coating solder a piece of metallic wire, having a knob on the other end, and let the wire be bent into the form of a hook for convenience in removing it. Having charged the jar in the usual way, remove the inner coating by means of a glass rod, and set it upon a table, now remove the tumbler by means of the thumb and finger, touching it only on the edge, and while you hold the glass in one hand suspended, the coatings may be brought in contact and handled when they indicate no signs of electricity; return the coatings in their place, and the jar may then be discharged in the ordinary way; thus proving that the charge resides in the glass and not in the coatings. The principal use of the coatings is to act as conductors in spreading the electricity over the surface.

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175. Where does the electricity reside in the Leyden jar? How proved?

to the experiments of Franklin, Dalibard and Delors, two French philosophers, had obtained similar results by the erection of spires; but the honor of the discovery is universally given to Franklin, as it was from his suggestions and recommendations that they were enabled to accomplish their purpose.

Obs. 1. Lightning is the result of the accumulation of large quantities of electricity in the atmosphere; sometimes one cloud is in the positive state, while another approaching it is in the negative state, and when they have approached sufficiently near the spark will pass from the positive to the negative cloud, producing the flash of *lightning*. In the space occupied by the flash, the air is suddenly and forcibly separated, and when it comes together again, produces a report which we call *thunder*.

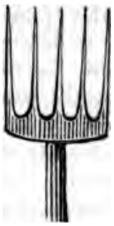
2. Sometimes the cloud in a positive state, instead of approaching a negative cloud, approaches the earth, which happens to be negative, and then the flash passes from the cloud to the earth: in this case some object is always struck, which is generally the highest object and best conductor; hence high buildings, such as steeples of churches, tall trees, masts of vessels, &c., are generally the objects injured or destroyed by lightning.

179. Notwithstanding the facility and danger of making these experiments, yet only a single case of death is recorded in repeating them, and that was the late Professor Richman, of St. Petersburgh, who approached too near the lower part of an insulated spire during a thunderstorm. He was examining the electrometer, which was standing near the lower extremity of the rod, when stooping a little to look more closely at the phenomena, a large globe of electric fire flashed from the conducting rod to his

178. Obs. 1. What is lightning?—What thunder?—2. What causes the lightning to strike?
179. What is said of Professor Richman?

l, and passed through his body, destroying instantly. A red spot was produced upon orehead, his shoe was burst open, and a part s vest singed; his companion was for some rendered senseless; the door of the room split and torn off its hinges.

30. The most important, and therefore most esting application of the theory of electri- is in the use of *lightning rods* to protect lings, ships, &c. It consists in erecting a illic rod beside the building, which it is in- ed to protect, it should be pointed at each emity, because points receive and impart the ric fluid silently. The upper end should ct above the highest part of the building, other should penetrate deep in the earth or ntact with water. Iron is generally used use it is cheaper, but copper is better be- e it does not so easily rust. The part that cts above the building, generally terminates number of points, thus



What are lightning rods?—How are they constructed?—What generally used?—What is the best, and why?—What is used for its?

and these are generally of silver, gold, or platinum, because those metals do not rust. The rod should be half an inch in diameter.

181. People are often led to inquire what are the best means of safety during a thunderstorm? If out of doors we should avoid trees and elevated objects of every kind; and, if the flash is instantly followed by the report, which indicates that the cloud is very near, a recumbent posture is considered the safest. We should avoid rivers, ponds, and all streams of water, because water is a good conductor, and persons on the water, as in a boat, would be the most prominent object, and therefore most likely to be attracted by the lightning.

182. If we are within doors, the middle of a large carpeted room is tolerably safe: we should avoid the chimney; for the iron of and about the grate, the soot that often lines it, the heated and rarified air that it contains, are all tolerable conductors, and should on that account be avoided lest they should be attracted by the lightning.

183. It is never safe to sit near an open window, because a draught of moist air is a good conductor and should therefore be avoided; hence we should close the windows on such occasions, as well for avoiding the lightning as the rain. In bed we are comparatively safe, for the

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181. Where is the safest place while out of doors in a thunderstorm?
182. Where is the most safe place in the house?—What places should be avoided?
183. What is said of sitting near a window?

feathers and blankets are bad conductors, and we are to a certain extent *insulated* in such situations. All these precautions are unnecessary in buildings well defended by lightning rods.

184. There is a variety of amusing experiments for illustrating the effects of lightning upon buildings by causing electricity to pass through the model of a house, a powder magazine, &c., exhibiting in miniature the effect of lightning upon buildings.

185. There was at one time much discussion amongst electricians respecting the relative advantage of balls and points in constructing lightning rods; but, agreeably to Dr. Franklin's original recommendation, points are now universally adopted, because they conduct away the electricity silently. To prove the correctness of this opinion, Dr. Franklin proposed the following experiment:

Exp. Attach one or more large flocks of cotton to the prime conductor, so as to resemble electrified clouds; when a point is made to approach them they collapse, recede, and quickly lose their electricity; when, on the other hand, they are approached by a ball they are attracted towards it, and the electric charge is very slowly dissipated.

186. The *aurora borealis*, and *aurora australis*, or the northern and southern lights, are supposed to be caused by currents of electricity passing through the higher regions of the atmos-

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184. What experiments referred to with houses, powder magazines, &c.
185. Why are points preferable to balls in constructing lightning rods? —What experiment was proposed by Franklin?
186. What is said of the aurora borealis and the aurora australis?

phere to or from the earth, in which case it must pass through such strata as are highly rarified, and this opinion is strengthened by the fact that the electric fluid will pass through an exhausted glass vessel, exhibiting much the same appearance as the light of the north. Shooting or falling stars are also considered to be of electrical origin.

GALVANIC ELECTRICITY—GALVANISM.

187. The term galvanism is used to denote the electricity produced by the corroding action of various materials on plates of different metals, such as that of oil of vitriol upon iron or zinc.

188. The common experiment of putting a piece of zinc on the surface of the tongue, and a piece of silver under it, and letting the edges come in contact over the tip of the tongue, was described by Sulzer, a German, in 1767, and was the first notice of any fact that comes under the denomination of galvanism. In this experiment the moment the metals come in contact a peculiar taste is perceived, and if the eyes be closed, a flash of light at the same instant.

189. No other fact of this kind was made known until the novel and wonderful experi-

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187. Explain the term galvanism?
188. Describe the experiment with silver and zinc.
189. What led to the discoveries in the science of galvanism?—Give the history of the discovery.

ments of Galvani, a Professor of Anatomy in the University of Bologna, in Italy, from whose name the term galvanism is derived.

Obs. The discovery was entirely accidental, as the following circumstances show. It happened in the latter part of 1789, that Madame Galvani, then an invalid, was advised by her physician to take, as a nutricious article of diet, soup made of the flesh of frogs. Some of these animals recently skinned for that purpose were lying upon a table in the professor's lecture room, near which a pupil was amusing himself by experiments with the electrical machine. While the machine was in operation, he happened to touch the leg of one of these animals with the blade of a knife which he held in his hand; the whole limb was convulsed at every spark taken from the machine. Galvani, it appears, was not present when this happened, but received a faithful account of it from his lady, who had witnessed with much interest the whole occurrence. Galvani lost no time in repeating the experiments, and in examining minutely into all the circumstances connected with them.

190. The nerves and muscles of animals are most easily affected by the galvanic influence.

Exp. 1. Place a living frog or a flounder upon a plate of zinc, and a piece of copper upon the upper surface of the animal, and connect the two by a piece of copper wire; every time the connection is made the animal is convulsed by the shock.

2. Let a person go into a dark room, put a piece of silver upon his tongue, and press a piece of tin foil against the globe of the eye; by making a communication between the two by a small piece of copper wire, at every contact a flash of light will be perceived in the eye.

191. By repeating and varying the experiments, Galvani soon found that any two metals would answer for his experiments, but that it

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190. What is said of galvanism on nerves and muscles?—Describe the experiment with a frog.—Describe that with the silver and tin foil.
191. What was the result of varying the experiments?

facts without any regard to theory; it is ject of the *atomic theory* to explain the c these facts, or, in other words, the reaso bodies thus combine.

Obs. The atomic theory, as it is called, was intro Dr. Dalton of Manchester, Eng.

231. It is assumed, according to this t that all bodies are composed of ultimate that is of atoms so small that they can divided, and that the weight represented proportions in which bodies combine, same as that represented by their ultimate consequently, knowing the former, we in latter.

Illust. Thus, hydrogen being the lightest of all bo can be weighed, its atom is represented by *one*, while being much heavier is represented by *eight*, and it is ary to employ the term atom here in the same sense bining number, equivalent number, &c.; hence, in s of water, instead of saying it is composed of one equi hydrogen and one equivalent of oxygen, we may s equal propriety it is composed of 1 atom of each and as the atom of hydrogen is 1 and that of ox the compound atom of water must be represented by 9.

332. All gaseous bodies unite in definit portions by volume, in the same manner lids and liquids unite by weight.

Illust. Thus, two measures of hydrogen united t oxygen form water; one measure of nitrogen gas u three measures of hydrogen, form the gas called amm hartshorn.

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231. What does this theory assume?—Give the illustration.
232. How do gaseous bodies unite?—How is it illustrated?

PART II.

NON-METALLIC BODIES.

233. As before stated,* there are fifty-four simple or elementary bodies, thirteen of which are non-metallic, and forty one are metals.

234. Of the thirteen non-metallic elements, four, namely, oxygen, chlorine, hydrogen and nitrogen, are gaseous bodies, bromine is a liquid, and the remaining eight are solids at common temperatures.

Table of non-metallic elements.

Gases.	*Liquids.*	*Solids.*	
Oxygen,	Bromine,	Iodine,	Carbon,
Chlorine,		Fluorine,	Boron,
Hydrogen,		Sulphur,	Silicon,
Nitrogen,		Phosphorus,	Selenium.

235. Nearly all the elementary bodies exist in the crust of the earth, in a state of combination. A few of them exist in so small quantities, and are apparently so unimportant, that if they were annihilated we should scarcely feel their loss; while others of them are so obviously necessary to the present order of things, that the

233. How many elementary bodies?—How many non-metallic?—How many metals?
234. How many of the non-metallic are gaseous bodies?—What are liquid, and what are solid?
235. In what state do elementary bodies generally exist, and what is their relative importance?—What are the subjects of Chapter I?

* See General Remarks.

least arrangement or alteration in their proportion or quantity would be destructive to the whole.

CHAPTER I.

Oxygen, Chlorine, Hydrogen, ***and*** *Nitrogen,* and their combinations with each other.

OXYGEN 8.*

236. Oxygen is one of the few elementary substances that occur naturally in the gaseous form, in which it constitutes about one fifth part of the atmosphere, and may be fairly considered as one of the most important, if not the most important substance, found about the surface of the globe. It enters largely into the composition of the crust of the earth, forming more than one fourth part of its weight. It forms a constituent part of animals and vegetables, and a constant supply of it is necessary to their support, and

236. What proportion of the air is oxygen?—And what its importance?—What part of the earth does it form?—What part of water?

* The figures after the names of substances in the titles of the sections, represent their combining number or equivalent; the latter term will be used in this treatise, on account of shortness and to prevent confusion. With regard to fixing upon the equivalent numbers representing the various substances described, I shall generally take the numbers given in the fourth London edition of Turner's Chemistry, as the nearest approximation to truth. The chief objection to these alterations from the old numbers is, that he has introduced fractions. To avoid the inconvenience of these, I shall in this work still adhere to whole numbers, and shall generally give that number the preference to which the fraction the nearest approximates. Thus the former equivalent for phosphorus was 12, Turner fixes on 15.7; as this approaches nearer 16 than 15, I shall adopt 16 in preference.

even their existence. Eight ninths of the weight of water is oxygen.

237. *Discovery and name.* Oxygen exists in the state of a gas in the atmosphere, and was discovered by Dr. Priestly in 1774. The term oxygen is from two Greek words, signifying *to form acid*, because it was supposed that no acid could be formed without its presence.

238. *Preparation.* It is generally obtained for the purposes of exhibition from the salt called chlorate of potash, from saltpetre, or from the substance called black oxide of manganese, either of which, by being heated to redness, will afford abundance of oxygen. All that class of bodies called *oxides or the rust* of metals contains it: all the different kinds of earths are oxygen combined with different metals.

Obs. For those who are not much accustomed to experimenting, chlorate of potash is preferable to either of the other materials, both from the simplicity of the apparatus required and from the success which generally attends the experiment. The nitre is dangerous to use, especially for those who are not in the habit of using it, and of course are ignorant of its peculiarities, and the oxide of manganese is frequently impure, and thus frequently renders the experiment unsuccessful; besides the chlorate of potash affords the purest gas, one ounce of which yields nearly two and a half gallons of oxygen.—Nearly all the methods for procuring oxygen require a furnace of some kind.

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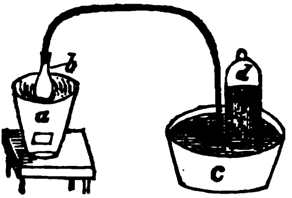
237. What is said of the discovery and the name of oxygen ?
238. What materials are used, and how is the gas separated ?—Which is preferable, and why ?—How much gas does the chlorate of potash yield ?—Describe the apparatus and the experiment.



Exp. The manner of preparing the gas may be understood from the accompanying figure; in which *a* represents a common portable furnace, filled with lighted charcoal, (almost any open furnace that will burn charcoal will answer the purpose,) *b* is a common florence flask containing from one half an ounce, to an ounce of chlorate of potash, according to the quantity of gas required; the flask communicates with the pneumatic trough *c*, by means of a leaden tube, where the gas is discharged into the water under the glass receiver *d*, (which has been previously filled with water, and inverted in the trough *c*,) and being lighter than the water, rises through it in bubbles as represented in the wood cut.*

When any other materials are used for preparing oxygen such as saltpetre, oxide of manganese, an iron bottle may be used, and should be heated to redness, carefully regulating the heat.

Rationale. Chlorate of potash is composed of three ingredients, oxygen, chlorine, and the metal called potassium. By applying heat the oxygen is expelled, and the chlorine and potassium remain in a state of combination in the flask, (the compound is called chloride of potassium.)

239. *Properties.* Oxygen exists in the form of a gas, is a little heavier than air, one pint† of it weighs about ten grains, while the same measure of air weighs about nine: it is transparent and invisible—slightly absorbed by water, has a

239. Describe the properties of oxygen.

* The teacher should here practise before his class by pouring gas or common air from one vessel to another, explaining how the receiver *d* can be filled with and inverted in the water of the trough, and the water still remain in the receiver, the cause of which is the pressure of the atmosphere.

† The measure, pint, quart, &c., will be frequently used in reference to gasses, because the terms are more readily comprehended, than the quantities represented by cubic inches.

powerful attraction for most bodies, combining with them, and causing that appearance, generally denominated *combustion;* hence, it is said to be a *supporter* of *combustion.* The process sometimes takes place at the ordinary temperature; as, when iron is exposed to damp atmosphere, the oxygen of the air unites with it, forming a red crust, called the *rust* of iron.

240. In every case, where oxygen combines with any other substance, the process is called *oxidation;* the substances (such as the iron) are said to be *oxidized* and the compounds are either *oxides* or *acids.*

241. All bodies that burn in open air, burn with far greater brilliancy in oxygen gas.

Exp. 1. Having filled a common wide-mouthed vial, of the capacity of a pint, as directed in the experiment (238) for procuring oxygen, immerse in it a lighted taper; it will burn with great brilliancy—now blow out the flame. Having removed the taper from the vial, again immerse it, and if there be the least spark of fire on it, the taper will rekindle with a slight explosion.

2. Having filled a vial of the same size with fresh gas, and attached a fragment of charcoal (made of the bark of some hard wood, such as hickory or maple) to a piece of wire, light the charcoal and plunge it into the gas; it burns with splendor, throwing out brilliant scintillations; but the combustion soon diminishes, and if no more oxygen be added, ceases entirely. If we now examine the air in the vial, we shall find it to be the well known substance called *fixed air*, or *carbonic acid*, which is a direct combination of carbon and oxygen gas.

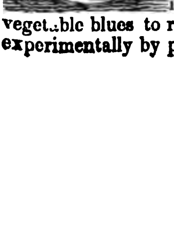
3. Iron, which in air only burns at very elevated temperatures, needs but a red heat to burn in oxygen, with a light

240. Describe the terms oxidation, oxidized, oxide and acid.

241. How do bodies burn in it?—Describe the experiment with the taper.—Describe the experiment for burning charcoal.—What is the product?—Describe the experiment with iron wire and the product.

which is almost as dazzling and insufferable to the eye, as the sun itself. A faint representation of it is given in the figure. A piece of fine iron wire spirally twisted, is introduced through the cork *a* of a bell glass or receiver filled with oxygen gas. To the lower end of this wire is attached a piece of thread, touched with sulphur, to ignite the wire in the first instance. As the gas is a little heavier than atmospheric air, its escape or mixing with the atmosphere, is prevented by placing the receiver in a basin filled with water. If we were to employ a common jar for the same experiment, then the little globules of melted wire, which drop during the process of combustion, would melt the glass, or if the bottom of the vessel be thin, fuse a hole through it without breaking the glass.— The product in this case is an oxide of iron.

Obs. The oxide of iron, formed by burning the metal in oxygen gas, differs from common iron rust, which is also an oxide of iron, only in the relative proportion of the oxygen. In all cases, therefore, where there are two oxides of the same substance, that which contains the smallest proportion of oxygen is called the *protoxide* (first oxide), and that which contains the largest proportion is called the *peroxide*. Thus the black globules formed by burning iron wire in the gas, form the protoxide, while common iron rust is the peroxide.



Exp. 4. Fill the jar represented in the wood cut with oxygen, and plunge into it a copper ladle, suspended by a copper wire, and containing a little sulphur, previously kindled by holding it in the flame of a lamp. The flame of the sulphur will be very much enlarged and exceedingly splendid. On examining the contents of the jar, we find that the oxygen, in combining with the sulphur, has formed an acid; this is proved, first by its sour taste, and secondly by its changing vegetable blues to red. (See 223, Exp. 1.) This is illustrated experimentally by pouring into the jar, before burning the sul-

phur, a little blue cabbage water, which, by agitation after the experiment, will become a bright red.

Exp. 5. Fill the jar used in the last experiment with the gas, and pour in a little of the vegetable blue; and having wiped the ladle perfectly dry, put in it a piece of phosphorus, about the size of a pea, and depressing the ladle into the middle of the jar, touch the phosphorus with a heated wire, it will immediately inflame and burn with a most intense light. Now agitate the jar, and we shall find the vegetable blue has been changed to a red, showing that an acid has been formed.

Exp. 6. Fill the jar again with the gas, and add the vegetable blue as before; now substitute for the phosphorus (having wiped the ladle perfectly dry) a piece of metallic potassium of the size of a pea, depress it into the jar, and apply the red hot wire as before mentioned, the potassium will burn with a brilliant white flame. Agitate the jar, the vegetable blue will become green, showing that an alkali has been formed by the combination of the oxygen in the vessel with the potassium.

242. In each of the above experiments, the product of the combustion was either an *oxide* or an *acid.*

Illust. Thus, the sulphur, charcoal, and phosphorus, formed *acids*, while the iron and potassium formed *oxides*. The first was an oxide of iron, the second an oxide of potassium, commonly called potash. It is also called one of the fixed alkalies.

243. In all cases of combustion in oxygen, the gas combines with the combustible body, and consequently the product is increased in weight by the process.

Illust. Thus, the iron, the potassium, &c., have increased in weight by the combustion, precisely as much as the gas has diminished.

244. If oxygen be suddenly compressed, it

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242. What is the product in all the preceding cases of combustion?—Illustrate it.
243. How is the weight affected, and what is the proportion of the variation?
244. What is the effect of compression on oxygen?—What experiment is referred to?

Exp. 3. Fill a tall vial or a glass tube, sealed
cally at one end, or closed with a cork as seen
cut, procure some metallic antimony and met
and pulverize them: these when thrown into
take fire, emitting brilliant sparks.

4. Into a jar of the gas plunge a piece of
cently dipped into spirits of turpentine; it v
spontaneously if the gas be pure.

5. Copper as well as gold leaf will fire sp
in chlorine gas. On immersing the metal sudd
gas, the two will unite with a flash of light, an
of gold or of copper will be formed.

6. One of the most useful and therefore most valu
ties of chlorine, is that of bleaching, by which anin
table colors are removed and destroyed. This may
ed by immersing a red rose, or any other colored
the absence of these a green leaf, previously mois
vessel of the gas, and in a few moments its color
charged. Calico may be substituted for the above

7. The bleaching properties of chlorine, may b
lustrated by pouring a little of the water that l
chlorine into a solution of blue cabbage, which
ately become colorless.

253. Dry chlorine has no bleachin
moisture is always necessary to produ
fect. It is known that muriatic acid
formed in this process, and it is suppose
water is decomposed, its hydrogen uni
the chlorine, forms muriatic acid, anc
gen with the coloring matter, decomp
thus destroys it.

254. The application and uses of cl
destroying noxious and pestilential ef
now a fact generally known. It was d
by Guyton Morveau, a Frenchman, an

---

253. What effect has dry chlorine, and what the moisture
254. What is said of noxious effluvia and the discovery of

y him to purify the foul air in the wards of ospitals.

255. It is supposed to act in the same manner n contagious effluvia; hence the chloride of me or bleaching powder is now generally used where such diseases prevail.

Illust. Thus in cholera, small-pox, &c., the chloride of lime put in vessels, and distributed about the dwellings. The alorine slowly separates from the lime, coming in contact ith the noxious vapors or effluvia, and thus is supposed to compose them. This process is called *disinfection.*

254. There have generally been described in ie books four combinations of chlorine and xygen, constituted as follows:

otoxide of Chlorine	composed of	1 atom of	Chlorine and	1 of	Oxygen.
roxide	"	1 "	"	4	"
loric Acid	"	1 "	"	5	"
rchloric Acid	"	1 "	"	7	"

Obs. The uses of the terms *prot* and *per* are the same here described in the observation of Exp. 3d (241). *Protoxde* signifies the smallest combination of oxygen in the oxides, nd *peroxide* signifies the highest; and in the same manner *rchloric acid* signifies the highest combination of oxygen ith chlorine in the acids of these two elements.

255. Late experiments render it propable that ie compound called protoxide of chlorine, is a ere mixture of the peroxide and pure chlorine.

256. *Peroxide of Chlorine* is a bright yel-

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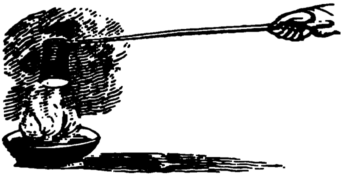
255. How does it act on contagious effluvia?—Give the illustration.
254. How many compounds of oxygen and chlorine.—And what is their mposition?—Define the terms *prot* and *per*, as used here.
255. What remark of the protoxide?
256. Describe the peroxide of chlorine, how procured?—What experient is made with it?—Give the rationale of the formation of the perox of chlorine.

ine of turpentine, and pour on it about the sa
nitric acid, freshly prepared according to the ab
and the whole will burst into flame and burn
seen by the accompanying wood cut.



Exp. 2. Pour some of the acid upon dry and w
it will take fire and throw off brilliant sparks.

3. Having put some of the acid into a sm
set it in some place where there will be no dange
plosion, and throw into it a piece of phosphorus
of a pea, and quickly retire into another part o
violent action takes place between the materials,
in about a half a minute the whole explodes throw
in every direction.

CHLORIDE OF NITROGEN—1

321. Nitrogen and chlorine combi
proportion only, forming an oily liqui

AMMONIA—17.

322. Ammonia in a pure state is a colorless gas, composed of one atom of nitrogen and three of hydrogen. It is known under various names such as *hartshorn*, *volatile alkali*, *alkaline air*, &c., but the most appropriate name is *ammonia*, so called because first found near the temple of *Jupiter Ammon*. It is the escape of this gas from the various compounds containing it, that produces the odor in the common smelling bottles.

Obs. The little bottles sold by the druggists and perfumers, under the appellation of *Preston salts*, consist of nothing more than the materials for liberating this gas very slowly and mixed with essential oils.

323. *Preparation.* Ammonia is easily prepared by putting into a florence flask equal measures of pulverized quicklime and sal ammoniac, so as to fill about one third part of the vessel, and applying the heat of a small charcoal furnace, or a chafing dish of coals as represented in the figure.

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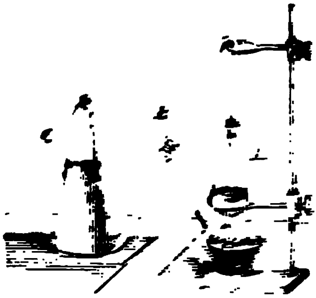
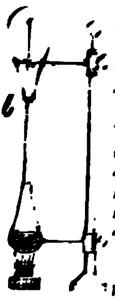
322. What is ammonia, and what its names?—What are Preston salts?
323. How is ammonia prepared?—What is the second method?



[illegible] containing [illegible] inverted [illegible] the same liquid [illegible] well for a receiver [illegible]

2. Another method consists in heating [illegible] which [illegible] than the gas [illegible] water. The ammonia is expelled and [illegible] inverted flask [illegible] are very useful in exp[illegible] ing with this gas these may be substitute[illegible] inverted flask, and also for collecting the quicksilver.



324. *Properties.* Pure ammo[illegible] a colorless gas, of an exceeding[illegible] and penetrating odor, which powerfully ir[illegible] the eyes, producing a copious flow of tea[illegible] has a sharp and burning taste. When [illegible] into the lungs, even much diluted with [illegible] produces a sense of suffocation. An a[illegible]

[illegible] Describe the properties of ammonia.

immersed in it dies almost instantly. It will extinguish burning bodies immersed in it, nor is the gas itself inflamed by them. It is, however, inflammable in a very low degree, for the flame of a taper, when immersed in it, is enlarged and tinged yellow before being extinguished. In pure oxygen, a jet of ammonia burns with a bright yellow flame.

325. Ammonia is rapidly absorbed by water, so that it is impossible to collect it over that liquid. One pint of water will absorb 700 of ammonia.

Exp. 1. The absorption of the gas may be illustrated by inverting, in a basin of water, a long glass tube, closed at one end, and filled with the gas collected over quicksilver. On opening the tube under water, the liquid will rise in it only a few inches; now close the end of the tube very firmly with the thumb, or the palm of the hand, and, removing it from the basin, invert it so that the water contained in it may run to the opposite end and moisten the whole length of the tube, and on re-opening it under water, (if the gas be pure,) it will instantly be filled with the liquid.

2. Substitute a piece of ice for the water by placing it under the mouth of the tube when filled with the gas, and standing over quicksilver; the ice will absorb it nearly as rapidly as the water.

326. Ammonia changes vegetable blues to green, and hence it is called an alkali.

Exp. This may be illustrated by substituting for the water used in the last experiment but one, a solution of blue cabbage. This on ascending into the tube will be instantly changed to green.

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325. What is the action between this gas and water?—What experiment is referred to?—Describe the 2d Exp.
326. What effect has ammonia on vegetable blue?

Illust. A slight degree of friction, as that wh made with a piece of phosphorus between two fo paper, will be sufficient to show the experiment.

445. Sulphur requires to be heate 500°, and oil, or coal gas cannot be in any temperature short of that commun flame itself; even an iron wire heated ness will not set fire to the gas.

446. Flame may be considered as gaseous matter; in other words, it is of exceedingly minute particles of vap to whiteness. The temperature of fla at all in proportion to the light, for in of hydrogen the light is so feeble as sc be perceptible by daylight, yet its tempe such as would heat solid bodies to w which is proved by holding in it small fine iron or steel wire, which are even the flame.

Exp. The experiment may be varied by sprink flame some finely powdered chalk, or calcined magn causes the light to be very much increased.

447. The luminousness of the flam last experiment was derived from the m the fineness of whose particles resembles degree that of the ignited carbon diffused ordinary flames. When the magnesia no combustion takes place, and no pe change, but the light results from the

445. What remark of sulphur and coal gas?
446. Define flame and the relative proportion of heat and l the experiment.
447. How can the luminousness of flame be explained?— inference?

power of the flame, which is actually cooled by the solid particles being thrown into it; hence there is no regular proportion between the light and heat emitted by flame.

448. In the flame of tallow, wax, oil, and coal gas, the brilliancy of the flame is owing to finely divided charcoal intimately combined with, and forming a part of the combustible substance. During the combustion, this charcoal, before in the state of an invisible gas, is separated from its chemical combination, and precipitated in the flame in the form of exceedingly minute particles, which, being heated to whiteness, produces the luminousness of the flame.

449. Imperfect flame arises from two causes, an excess, or deficiency of carbon; if there be an excess, the flame will smoke, as in the combustion of rosin, spirits of turpentine, inferior oil, &c.: if there be a deficiency of carbon, it will give but little light, as in the flame of hydrogen, and spirits of wine.

Illust. Hence, by adding to spirits of turpentine, as much spirits of wine as will afford sufficient carbon, it will produce a dense white flame. This is the spirits of turpentine mixture now extensively used instead of oil, under the name of *Jennings' patent mixture.*

Obs. The advantages of this mixture over oil are, that the wick never requires snuffing. The lamps are cleanly in their appearance, and continue to burn until the last drop of liquid is expended; the brilliancy of the flame continuing nearly the same to the last. One of the disadvantages

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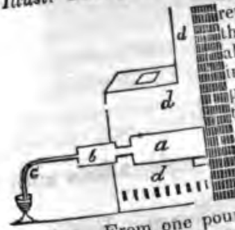
448. What is said respecting the brilliancy of flame, and how is it accounted for?

449. What are the causes of imperfect flame?—Give the illustration.

phrey Davy, in 1807, by placing a piece of pure potash between the poles of a powerful galvanic battery. A large quantity of oxygen was liberated at the positive pole, and globules of high metallic lustre, resembling quicksilver, appeared at the negative. The metal obtained in this manner was in very small quantities, but another method was soon adopted by Messrs. Gay Lussac and Thenard, of France, by which they obtained it in much greater quantities, by heating iron turnings in contact with pure potash, which is an oxide of the metal.

501. It may be conveniently prepared by heating to whiteness, a mixture of potash, charcoal and iron turnings, in a wrought iron bottle, as represented in the wood cut.

Illust. The figure represents a vertical section of an air fur nace, in which the letters *d d d* r represent the passage for the air ; the iron bottle containing the mate als ; *b* is also an iron bottle for rece ing and condensing the vapor of potassium, and connected to the tle *a* by a short piece of tube ; *c* smaller tube for discharging th pors that are not condensed in bottle *b*, and dips down into a containing naphtha or spirits pentine. From one pound of potash, two of iron tur and half a pound of charcoal, I have obtained an ounce half of potassium.



502. *Properties.* Potassium is a white resembling quicksilver, having the whiten

501. Describe the method given in the book.
502. Describe the properties of potassium.

tin, and is so soft that it may readily be kneaded in the fingers, and is considerably lighter than water. With a fresh surface it has a strong metallic lustre, but is instantly tarnished by exposure to air, exhibiting at first a bluish cast, like that of a recent cut surface of lead, and is afterwards covered with a white crust, which is pure potash.

503. Potassium has a powerful affinity for oxygen, and will take it from any other compound that contains it.

Illust. When thrown upon water it decomposes that liquid moving over its surface with rapidity and combining with both its constituents with the phenomenon of combustion, accompanied by a beautiful rose-colored flame. The oxygen of the water combines with a part of the metal, forming an oxide (potash) which is dissolved in the water, while the hydrogen takes up another portion of the metal, forming a gaseous compound called *potassiuretted hydrogen*, which inflames spontaneously when it comes in contact with the air, and burns with a rose-colored flame as before mentioned.

504. *Oxides* of *potassium.* There are two combinations of potassium with oxygen, the *protoxide* or potassa, which is composed of 1 atom of each ingredient, and the peroxide, composed of 1 atom of metal to 3 of oxygen.

POTASSA.—*Potash.*—48.

505. Potassa is a white crystaline solid, and is obtained in a state of purity only by burning

503. What is said of its affinity for oxygen?—Give the illustration.
504. Describe the compounds of potassium and oxygen.
505. What is potassa, and how does the article differ, as differently prepared?—Give the substance of the observations.

to resemble that of the planet Jupiter.

563. It is not oxidized by exposure
is quite malleable, and is rolled out into t
called tin foil, which is extensively u
arts. It is used by dentists in pluggin
teeth.

564. Tin may be distinguished fro
metals by giving a peculiar crackli
when bent. It melts at the temperatu
and when heated to whiteness in the
it takes fire and burns with a splen
flame, producing an oxide of this met

565. Tin is most extensively used i
in combination with other metals. U
lead, it forms solder, used by the tin
soldering their vessels. Common ti
made of plates of sheet iron covered w
coating of metallic tin, prepared by di
sheets of iron, previously cleansed, in
tin. This is sometimes called block t

566. Copper tea kettles and other ve
same metal used for domestic purpos

prepared by first cleansing the surface of the copper and then melting the tin in the vessel, a thin coating of which will adhere to the copper, and the rest, in a melted state, is poured off.

567. Block tin vessels, such as tea-pots, coffee urns, &c., are tin, containing about five or six per cent. of brass and a small quantity of metallic antimony. The articles are cast in copper moulds, generally in pieces, and afterwards soldered together and polished.

568. Britannia ware is made of the same materials as the block tin ware, except that, for the brass used in the block tin, copper is here substituted. The articles are formed by first casting the metals into thin sheets, and then beating them up into the desired forms by hammers and other instruments.

569. There are no mines of tin which are wrought for obtaining the metal in the United States. It is chiefly imported from the mines of Cornwall, in England, or from China and the East Indies.

570. There are two oxides of tin, the protoxide and the peroxide. The latter is a pale yellowish powder, and is used in the arts, under the name of *putty of tin*, for polishing metals, and when melted with red lead it forms

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567. What is the composition of block tin vessels, and how are they made?
568. Describe the britannia ware, and how is it made?
569. What are the sources of tin?
570. What is said of the oxides of tin, and to what uses are they applied?

Obs. The annual product of the *Oural* ... less than 5 millions of dollars; *that from* ... America 15 millions, 500,000 dollars of *whic*... obtained from the gold mines of North Caro... coined at the United States' mint from Decem... November 18th, 1834, amounts to 2,835,900 do...

634. Immense quantities of thi... employed in the arts, in the manufa... rious useful and ornamental article... it is generally alloyed with silver o... with both.

Obs. 1. Alloys of gold with silver form the ... while those of gold and copper have a reddish... light colored clothing much less than the yell... gold coin of the United States is composed ... weight of gold, and 1 part of an alloy of sil... hence the coin is $\frac{1}{12}$ alloy, or 2 parts in 24.

2. The fineness of gold is expressed in *car*... carat signifies some part of 24. Thus an alloy ... parts of gold and 12 of copper or silver, is ... carats fine; 18 of gold and 6 of copper forms ... 18 carats fine; 22 parts of gold and 2 of allo... pound that is 22 carats fine. The last are the pr... constitute the coin of the United States, and ... alloy that is generally wrought for the purpos... chief object in the combination of other metals ... render the compound more durable. Gold alon... ness, would wear away too rapidly.

635. Gold is extensively emplo... processes of gilding, of which ther... Those in most general use are t... *amalgamation*, generally called *wa*... and that by means of *gold leaf*, ... for gilding on wood.

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634. What is said of the uses and applications of th... the term carat explained?

635. Describe the processes of gilding?

Illust. 1. Water gilding is performed by putting leaves of pure gold in quicksilver, heated nearly to the boiling point; this forms the amalgam. The article to be gilded is made perfectly clean, is then covered with the amalgam, and the mercury evaporated by means of a charcoal fire. A thin coating of gold will be found covering the metal, and is afterwards burnished. It is thus that buttons, watch-cases, jewellery, and all kinds of gilt ornaments are prepared.

2. Gilding on wood is performed by first priming the article with several coatings of linseed oil, whiting, and glue water, then covering it with gold sizing, upon which the gold leaf being placed readily adheres. This kind of work cannot be burnished, but may be cleaned with a soft brush and water. The above is the method of gilding signs, picture frames, &c.

636. There are two or three oxides of gold, but they have no uses in the arts, and their constitution is not perfectly settled.

Obs. There is a compound called the *purple of Cassius*, which is prepared by adding proto-muriate of tin to a dilute solution of gold in nitro-muriatic acid; a purple precipitate falls down, which is found to be composed of peroxide of tin, water and gold. This, when mixed with pounded flint glass and used, forms a purple enamel, which is employed to give the decate pink color to china ware.

637. *Chlorides.* Two or three chlorides of old have been described by chemists, only one which has much interest in a practical point view, namely, that which is formed when the tal is dissolved in nitro-muriatic acid.

bs. If this solution be agitated with sulphuric ether, the e of the gold will be taken up by the ether, forming what een called the *ethereal solution of gold*, which is someused for gilding on steel.

p. Having prepared the solution according to the above ons, a lancet blade, or any other polished steel, on being

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Vhat is said of the oxides of gold?—Describe the purple of Cassius se.

escribe the chlorides, the ethereal gold, and its use.

679. *Carbonate of Potassa—Pearlash.* This is an extensive article of commerce, and is much used for domestic purposes, especially in the rising of bread and other like compounds. It was formerly called ***salt of wormwood, salt of tartar***, &c.

Obs. It is prepared by heating in large oven shaped furnaces the common or crude potash (described 505,) by which process the carbonic acid formed in the combustion, combines with the potassa, and the coloring matter is burnt out leaving it of a pearly whiteness, and hence the name ***pearlash***.

680. ***Bicarbonate of Potassa, celeratus saleratus.*** This is formed, by saturating the carbonate with carbonic acid, by which means another equivalent of acid is combined with the potassa.

Obs. The commercial article resembles the pearlash in appearance, and is used for the same purposes. In domestic uses, especially in rising bread, it is preferable to pearlash, because it contains twice as much carbonic acid.

681. *Carbonate of Soda*, is a crystalline salt obtained from barilla or kelp, (516) or from the decomposition of Glauber's salt, and is considerably used in the arts and for domestic purposes. It is also used in preparing the

682. *Bicarbonate of Soda.* In commerce, this article is more generally called *supercarbonate.* It is used in preparing soda powders, and contained in the blue paper from which the gas

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679. Describe the carbonate of potassa, its uses and preparation.
680. Describe the bicarbonate of potassa, its names, preparation and uses.
681. Describe the carbonate of soda, its preparation and uses.
682. Describe the bicarbonate of soda, its names, preparation and uses.

scapes in the effervescence The white paper ontains an acid called tartaric, which, displacing he carbonic, unites with the soda and forms tartate of soda.

683. *Carbonate of Lime.* This is one of the most abundant of all mineral substances. It is known by the names, *lime stone*, *chalk*, *marble*, &c., and is always formed where lime is exposed to the atmosphere. Carbonic acid, which constitutes nearly one half the weight of the carbonate, is expelled by a red heat, and *quicklime* remains.

Obs. The uses of marble and limestone, in building and making lime, are so well known, that no explanations are necessary.

684. *Carbonate of Magnesia* is sold by the druggists and apothecaries in little cubical cakes or lumps, and frequently called *white magnesia.* It is chiefly used in medicine.

685. *Carbonate of Lead, White Lead, Ceruse.* This article is extensively used as a pigment. It is formed by exposing sheets of lead to the action of the vapor of vinegar and carbonic acid mixed with air. The three ingredients are necessary to the successful manufacture of this article.

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683. Describe the carbonate of lime, its names, sources, and uses.
684. Describe the carbonate of magnesia.
685. Describe the carbonate of lead, its names, uses, and preparation.

FULMINATES OR CYANATES.

686. We have before mentioned (4 fulminating mercury and silver as con of the cyanic acid, and the oxides of th tals. The composition of the cyanic aci yet fully settled; most chemists regard compound of cyanogen and oxygen, others enumerate hydrogen as one of ments. As its composition is still so doubtful, it has been proposed to conti name *fulminic* acid, first applied by Lie

687. ***Fulminate of Mercury*** is the ce compound of which torpedoes and cracl made; it has the appearance of a grayi der, but, when closely examined, is founc sist of fine crystalline grains, which exp a slight degree of heat or friction; whei with oxide of tin and starch, it is us priming powder for fire-arms.

688. *Fulminate of Silver* is a co analagous, both in its composition and ties to the preceding one, but far more ous to manage, from the readiness witl it explodes from the slightest friction It consists of fine grains, having the app of fine white sand. It is chiefly used poses of amusement.

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687. What is said of the fulminate of mercury ?
688. What is said of the fulminate of silver ?

FERROCYANATES.

689. Ferrocyanates are compounds of ferrocyanic acid and a salifiable base. These compounds were formerly called ferroprussiates; they are complicated in their nature, the ferrocyanic acid being composed of cyanogen, hydrogen, and metallic iron. There are only two of these salts used in the arts.

690. *Ferrocyanate of Potassa*, formerly called *triple prussiate* of potash, which name is still retained in commerce and in the arts. It exists in flat, lemon yellow crystals, prepared by heating pearlash and iron with animal matters, such as dried blood. The salt thus formed is dissolved out by water and crystallized. It is chiefly used for preparing the prussian blue.

691. *Ferrocyanate of Iron*. This compound has been long known under the name of *prussian blue*. It was discovered by a manufacturer of colors, at Berlin, in 1704, and is prepared by pouring a solution of ferrocyanate of potassa into another of the sulphate of iron.

Exp. Prepare a solution of ferrocyanate of potassa, and then dissolve a little copperas in water and mix the two liquids, a deep blue precipitate will be formed, which is the prussian blue.

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689. Describe the ferrocyanates.
690. Describe the ferrocyanate of potassa.
691. Describe the ferrocyanate of iron and the experiment.

CHROMATES.

692. Chromates are combinations of chromic acid with different bases, and chromic acid, as we have before shown (610), is a combination of metallic chromium and oxygen. Nearly all the combinations of chromium are colored, and many of them are used as pigments, and highly valued, both for the brightness and durability of their colors.

693. *Chromate of Potassa* is a lemon yellow salt, and often called *yellow chromate*, to distinguish it from the one next to be described. It is prepared from a native ore called *chromate of iron*, by heating it with nitre, and dissolving out the chromate of potassa by hot water.

694. *Bichromate of Potassa*, often called *red chromate*, are flat crystals, having an exceedingly rich red color, and consists of two equivalents of acid and one of the base.

695. Both chromates are extensively used in calico printing, and in dyeing.

696. *Chromate of Lead—chrome yellow*. This compound is familiarly known in commerce and in the arts as a paint. It has taken the place of the *king's yellow* and *patent yel-*

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692. Describe the chromates.
693. Describe the chromate of potassa.
694. Describe the bichromate, and the uses of both.
695. What are the uses of the chromates of potassa ?
696. What is said of the chromate of lead, its uses and preparation?—What is the experiment ?

low, which were formerly almost the only articles used for that purpose. It is prepared by pouring the solution of chromate of potassa into another of sugar of lead.

Exp. Pour a solution of sugar of lead into one of the yellow chromate of potassa, the chromate of lead will be precipitated in a beautiful yellow powder.

PART IV.

VEGETABLE CHEMISTRY.

General Remarks.

697. The co[illegible]f vegetable and animal substances c[illegible]hat department denominated *orga[illegible]ry*, to distinguish it from that which we [illegible] thus far considered, and which constitutes *in[illegible]anic* chemistry.

698. 1. Vegetables a[illegible]animals are distinguished from all [illegible]stances, by having the principle calle[illegible]

2. They are nearly [illegible]mposed of the same elements combined in different proportions.

3. They are all decomposed by a red heat.

4. They cannot be produced by art.

699. The necessary ingredients of vegetables are carbon, hydrogen, and oxygen, in addition to which some contain nitrogen. These ingredients constitute the *ultimate elements*, and their separation from each other constitutes what has been called *ultimate analysis*.

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697. What is organic and what inorganic chemistry?

698. What are the four points which distinguish animals and vegetables from other substances?

699. What is meant by ultimate analysis and ultimate elements, and what is the composition of vegetables?

700. The elements of vegetables are so combined in nature, as to constitute distinct and definite compounds, which exist already formed in the plant, and are denominated *proximate principles.*

Illust. Such are *sugar*, *starch*, *gum*, &c. Wheat flour, though obtained from a vegetable, is not a proximate principle, but it is composed of two, namely, starch and gluten, or vegetable glue.

In our remarks on vegetable chemistry, we shall be chiefly occupied with a description of its proximate principles.

PROXIMATE PRINCIPLES OF VEGETABLES.

701. The constitution of vegetables has not yet been sufficiently determined to admit of a purely scientific classification. We shall examine them in the following order:

1. Those proximate principles which contain more than a sufficient quantity of oxygen for converting all its hydrogen into water; these bodies have an excess of oxygen, and constitute the *vegetable oils.*

2. Those principles that have an excess of hydrogen, and are of an oily, resinous, or alcoholic nature.

3. Those where hydrogen and oxygen are in the same proportions as in water; such are sugar, starch, gum, and woody substances.

4. Those which contain, besides the three

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700. What is said of proximate principles, and how is the subject illustrated?

701. What is the classification of the proximate vegetable principles?

elements noticed in the last paragraph, nitrogen as one of their ingredients; this division constitutes the class of substances denominated *vegetable alkalies.*

5. Those principles which do not, as far as we know, belong to either of the above classes; such are *coloring matter, tannin, yeast, &c.*

CHAPTER I.

VEGETABLE ACIDS.

These may all be obtained in crystals at common temperatures.

702. *Acetic acid* exists in the sap of many plants, is formed in the destructive distillation of many vegetable substances, and constitutes the acidifying principle of common vinegar. It is largely used for domestic purposes, and in the manufacture of sugar of lead and white lead. The compounds of this acid with bases, are called *acetates.*

Illust. Thus sugar of lead is the acetate of lead; verdigris is the acetate of copper.

703. *Oxalic acid* exists ready formed in several plants, especially in the leaves of common sorrel, and also in those of wood sorrel, in combination with potassa, constituting the *binoxa-*

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702. Describe acetic acid, its sources, uses, and combinations.
703. Describe oxalic acid, its sources, preparation, and use.

late. It is formed artificially by heating sugar or molasses with nitric acid, and is much used in cleaning brass and other metals. It is a powerful and fatal poison.

704. *Tartaric acid* exists in the juice of many acid fruits, in combination with lime or potash, such as the tamarind, the grape, &c. Combined with potassa, it forms *cream of tartar*, which is the bitartrate of potassa.

Illust. This salt exists in the crude state on the sides and bottom of wine casks, where it is deposited from the wine, a source whence all the cream of tartar and tartaric acid of commerce is obtained. This acid, in the state of powder, is extensively used in the manufacture of soda powders. Rochelle salt is a tartrate of potassa and soda. Tartar emetic is the tartrate of antimony and potassa.

705. *Citric acid* exists in abundance in the lime and lemon, and has an agreeable flavor.

706. *Malic acid*, from *malum*, an apple, exists native in that fruit, as well as in the orange, gooseberry, currant, grape, &c. The flavor of most fruits is owing to the presence of citric, tartaric, and malic acids.

707. *Gallic acid* exists in the *nutgalls* which grow upon the oak, in consequence of the puncture of an insect that deposits its egg in the spot, and the young insect is found in the centre of the nut. It exists also in the bark of many trees, in the tea leaves; and with tannin and sulphate of iron forms ink and black dyes.

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704. Describe tartaric acid, its sources, uses, and preparation.
705. What is said of citric acid ?
706. What is said of malic acid ?
707 Describe gallic acid, its sources and uses.

[illegible]. *Benzoic acid* exists in the gum called [illegible]*in*, and is used in many medicinal prepara-[illegible]s. It constitutes the peculiar aromatic taste [illegible] odor of *paregoric*.

[illegible]. *Kinic* sometimes called *quinic acid*. [illegible]s in peruvian bark in combination with lime [illegible]ming the *kinate* of lime.

CHAPTER II.

[illegible] PRINCIPLES THAT HAVE AN EXCESS OF HYDROGEN.

[illegible]. OILS are characterized by a peculiar [illegible]ous feel, inflammability, and by their inso-[illegible]ty in water. They are either *fixed* or *vo*-[illegible] The former give a permanently greasy [illegible] while the latter, though they pro-[illegible] disappears by gentle heat.

[illegible] *oils* are usually obtained from the [illegible] such as the almond, flaxseed, [illegible] the olive or sweet oil is ob-[illegible] the pulp which surrounds the stone. [illegible] absorb oxygen, pro-[illegible] and a tendency to become solid,

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[illegible] use.

[illegible] oils and how they are

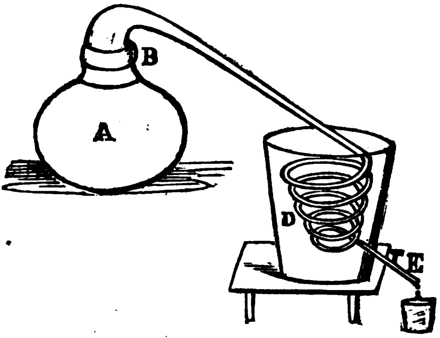
[illegible] of fixed oils and how are they affected by

of which the linseed oil is a remarkable instance; hence the vegetable oils, which have this property in a high degree, are called *drying oils.*

Obs. Flaxseed oil is called *linseed* from *linum*, the Latin name of the plant. This oil dries rapidly, and hence is a valuable material in painting. The kernel of the hickory nut, butternut, beech nut, sunflower seed, cotton seed, &c., contain much oil; palm and castor oil are used in medicine, the former is obtained from a large species of bean called *castor bean.*

712. *Volatile oils* constitute the peculiar odor of plants, and are obtained by distilling them with water, which prevents them from being burnt.

Illust. This process is performed in an apparatus called a *still.* A representation



of which may be seen in the accompanying woodcut; in which A represents the kettle or boiler containing the materials: B the tube for transmitting the volatile matters terminating in a coil termed the *worm*, which is surrounded by cold water in the

712. What are the volatile oils, what their sources, and how are they obtained?

[illegible] D, where the liquids are condensed and drawn [illegible] E.

[illegible] 3. Volatile oils have a penetrating or [illegible] taste; they are soluble in alcohol, a [illegible] slightly soluble in water.

[illegible] mixed with the former, they constitute essences; [illegible] distilled with the latter, they form the various distilled [illegible] water, lavender water, &c. The cologne [illegible] different article; it consists of alcohol hold- [illegible] of the volatile oils.

[illegible] Oil of turpentine is the most important [illegible] oils. It is obtained by distilling [illegible] which is a product of the pine: [illegible] more commonly called, spirits of [illegible] volatilized in the still, and condensed [illegible] while a brittle substance is left in [illegible] rosin.

[illegible] turpentine is extensively used in the arts [illegible] the composition of varnishes, paints, &c. [illegible] seed, peppermint, caraway and nutmeg, [illegible] medicine, and are occasionally employed [illegible] purposes.

Camphor [illegible] many of its properties re- [illegible] oils, and exists native in the [illegible] camphor, which is a species of the [illegible] the *Laurus camphora.*

[illegible] by sublimation. It is insolu- [illegible] in which state it is much [illegible] odor. It evaporates at all [illegible] noxious to insects, and [illegible] it is one of the safest [illegible] woolens, &c., from the action

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[illegible] volatile oils, and what are essences and [illegible]

[illegible] turpentine, its preparation and uses? [illegible] its sources and uses.

of moths and other troublesome insects during the warm season. All that is necessary, is to place a piece of champhor in the bottom of a close drawer, box or trunk which contains the article, and as long as any camphor remains, the articles are protected from insects.

716. *Resins* are the dried juices of plants, of which common rosin is the most familiar instance. They are solid at common temperatures, brittle, tasteless and inodorous. They are sometimes pure and sometimes contain essential oils and occasionally are mixed with gums, constituting what are called *gum-resins*, of which *gamboge*, *aloes* and *myrrh* are examples.

717. *Cooutchouc*, commonly called *gum elastic* or *indian rubber*, is the solidified juice of the *Jatropa elastica*, and of the *Haevea caoutchouc*, indian rubber trees of South America. It is also contained in some other trees. The juice has a milky appearance and is blackened by drying it over smoky fires, and the same effect is produced by long exposure to air and light. It is insoluble in water, but soluble in ether and oils, and may be again obtained in the solid form by evaporating the oil, by which means it is applied to various useful purposes.

718. *Wax* is nearly allied in its nature to a fixed oil. It exists in the pollen of many flowers. It forms the covering of the leaves of many plants and trees, as the cabbage, &c.

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716. What are resins, and with what are they mixed?
717. Describe cooutchouc, its sources, properties and uses.
718. What is said of wax and bayberry tallow?

It also forms the envelop of the fruit of th bayberry, &c., giving them their p glossy appearance.

Obs. The *bayberry* contains so much wax as to fi in small quantities for domestic purposes. It is obta boiling the berry in water, by which means the wax is ted. It has a greenish color, and is sold under the name berry tallow, and is mixed with tallow for candles.

719. *Beeswax* differs slightly in its comp tion from the article above described, and it is produced by bees that are fed on sug alone, it must be regarded as a modified anim product. It is bleached by exposure to the su in thin ribbands or shavings; it is also bleache by chloride of lime, and sold under the name o white wax.

720. *Alcohol*, or *spirits of wine*, is the intoxicating principle of all spiritous or vinous liquors. It is formed by the fermentation of certain vegetable juices, the process of which will be explained in another chapter. Alcohol is generally procured by distilling brandy, rum, or gin, and condensing the more volatile portions. The chief difference between these liquors and alcohol is, that the former contain more water. Alcohol is highly inflammable, and burns with a pale blue flame when strong, and yellowish, when it contains much water.

721. *Ether* is a liquid more volatile than al-

719. What is said of beeswax and white wax.
720. Describe alcohol, its preparation, and the difference between it and the intoxicating drinks commonly used.
721. What is said of ethers?

cohol, and is formed by distilling that liquid with a strong acid. The kind of ether takes its name from that of the acid employed; hence we have sulphuric ether, nitric ether, muriatic, acetic, &c. Sulphuric ether is most generally used, and consequently best known.

722. Pure alcohol may be considered as a compound of 1 equivalent of olefiant gas, 14, and 1 of water, 9; its atom is therefore 23, while sulphuric ether may be regarded as composed of 28 parts, or two equivalents of olefiant gas, and 9, or 1 equivalent of water; its atom is consequently 37.

CHAPTER III.

SUBSTANCES WHICH CONTAIN OXYGEN AND HYDROGEN IN THE PROPORTIONS TO FORM WATER.

723. Sugar is contained in ripe fruits, and in the sap of many trees, and in the roots of some vegetables, instances of which are met with in the grape, the sugar maple, sugar cane, and in the common garden beet.

724. Most of the sugar of commerce is pre-

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722. What may be considered as the composition of alcohol and sulphuric ether?

723. What is the subject of Chapter III, and what are the sources of sugar?

724. What is the source of the sugar of commerce, and how is it prepared?

pared from the sugar cane, (Arundo saccharifera,) by boiling it down until it will separate on cooling into fine crystalline grains.

725. *Molasses* or *treacle* is the thick part of the syrup which drains from the sugar, and does not readily crystallize; the sugar is afterwards refined and formed into cakes, which are termed loaf sugar.

726. *Starch* is an abundant product of the vegetable kingdom, being the chief ingredient of most varieties of grain, and of the roots of some vegetables, especially the potato.

Fact. It is readily procured from wheat flour, which consists chiefly of starch and gluten, the former of which is slightly soluble in water, while the latter is not. By letting a small current of water fall upon the dough of wheat flour contained in a piece of linen, the starch is washed away, but the gluten remains in the linen; most of the starch will, by standing a while, be deposited in a white powder upon the bottom of the vessel, which is tasteless and inodorous, and nearly insoluble in alcohol, ether, or cold water, but soluble in boiling water, and is not deposited on cooling. The best test of its presence is a solution of iodine, which produces a beautiful blue.

Exp. Prepare a solution of starch in boiling water, and when cold pour into it a single drop of an alcoholic solution of iodine, a fine deep blue will be formed. Indian *arrow root*, *tapioca*, and *sago*, are of a similar nature to starch.

727. *Gum* is found in a great variety of plants and trees; thus the cherry, plum, and peach tree, yield a gummy substance, but the purest kind is that which is obtained from a species of the *acacia* tree, growing in Arabia and some parts of Africa, whence it derives the

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725. What is molasses or treacle?
726. Describe starch, and the manner of preparing it.
727. Describe gum, its sources, uses, &c.

name of *gum arabic*. It is procured in such quantities as to furnish most other countries with the article. It contains much nutriment; the Moors are said to live on it almost entirely during their harvest; six ounces a day being sufficient for an individual. Gum is soluble in water, but insoluble in alcohol; it is extensively used in glazing calicoes and other goods, as well as in medicine.

CHAPTER IV.

VEGETABLE ALKALIES.

728. These substances, according to Dumas, besides containing oxygen, hydrogen, and carbon, also contain *nitrogen*. They are generally insoluble in water, and partially soluble in cold alcohol, but are quite soluble in boiling alcohol.

729. The vegetable alkalies are supposed in all cases to exist in the plant in combination with some native vegetable acid constituting a salt; to obtain the vegetable alkali therefore, we have only to present some stronger alkali that will combine with the native acid, the vegetable alkali being set free will, from its insolubility, be

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728. What is said of vegetable alkalies?
729. What is the state in which the vegetable alkalies exist in plants, and how are they obtained?

precipit[illegible] to the bottom. We first boil the substa[illegible] water, which dissolves the vegetable sal[illegible] then add potash soda or ammonia, and the [illegible]etable alkali is precipitated. It may then be [illegible]red on a filter and allowed to dry. By this p[illegible]ess, all the vegetable alkalies may be obtained.

730. [illegible]*rphia* is the active principle of opium or that [illegible] and was discovered by a German [illegible] 1803. It was the first vegetable [illegible]red. Another principle called *narco*[illegible]tained in opium, to which the subsequ[illegible]rious effects of this medicine are ascri[illegible]h as headach, sickness of stomach, &c. [illegible]eparating the morphia and combining it [illegible]ulphuric acid a sulphate of morphia is fo[illegible]d, by administering which we may secure th[illegible] good effects of opium and avoid the bad.

731. ***Qunia*** or ***Quinine*** is the active principle contained in the peruvian bark, and is obtained in the same manner as morphia, and given in the form of ***sulphate*** of ***quinine.*** It is much used as a remedy in fever and ague.

732. ***Strychnia*** is the poisonous principle contained in the St. Ignatius' bean ; it is also contained in the ***Bohon upas*** or the celebrated poisonous tree in the island of Java.

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730. What is said of morphia ?
731. What is said of quinine ?
732. What is said of strychnia ?

Obs. It is said, that criminals in that island were formerly executed by darts poisoned by this substance, and that on being wounded they trembled violently, uttered piercing cries, and perished in frightful convulsions in ten or fifteen minutes.

733. *Picrotroxia* is the bitter and poisonous principle contained in the plant called *coculus indicus.* It is the substance used to poison fishes.

Obs. For this purpose, it is mixed in fine powder with flour, which is made into paste and thrown into the water, the fishes partaking of it become intoxicated and come to the top of the water where they are easily taken. It is used by the brewers to put into beer as a substitute for alcohol in producing the exhilarating effect.

734. *Emetia* is the active principle of the emetic powder called *ipecacuanha,* or more frequently *ipecac.*

Sanguinarina is the active principle of blood root, (*Sanguinaria canadensis,*) *nicotine,* of tobacco, *piperine,* of black pepper.

CHAPTER V.

SUBSTANCES WHICH, AS FAR AS WE KNOW, DO NOT BELONG TO EITHER OF THE PREVIOUS CHAPTERS.

735. *Coloring matter.* Of this the vegetable kingdom is rich; saffron produces a fine yellow,

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733. What is said of picrotoxia?
734. What is said of emetia, sanguinarina, nicotine and piperine?
735. What is said of coloring matter?

PART V.

ANIMAL CHEMISTRY.

744. **The chief circumstances which serve to distinguish animal from vegetable matter, are the presence of nitrogen; their strong tendency to putrefy, and the highly offensive gaseous products of their putrefaction. The presence of nitrogen, however, is not a decisive evidence of animal matter, inasmuch as the vegetable alkalies contain it, and the animal oils do not.**

Obs. As we have already exceeded the intended limits of this work, we shall be compelled to be more brief in this part of the subject than was originally intended, and shall therefore confine ourselves to a very short description of the most important proximate principles.

745. The first of these which we shall notice is *fibrin*, which constitutes a large part of the flesh or muscular portions of animals. It exists in the blood in the state of solution, and is the cause of its coagulation when drawn from the body. It is of such a nature, that when once solidified, it cannot be again dissolved without changing its properties. It is readily procured by washing all the coloring matter from the lean parts of beef. It is a grayish white solid, which

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744. What are the characters of animal substances?
745. What is said of fibrin?

in the moist state is exceedingly disposed to putrefy.

746. *Albumen* is best procured from the white of eggs, which consist almost solely of this principle. It is contained in the serum or white part of blood, on account of which that article is much used for clarifying sugar. The most remarkable property of albumen, is the readiness with which it coagulates from heat by the action of acids or alcohol.

Obs. 1. The action of heat in coagulating albumen, renders it useful in clarifying coffee and various other liquids. Thus, in clarifying coffee, the white of an egg is mixed with it, and coagulates by boiling, and, becoming heavier, falls to the bottom, entangling and carrying down with it those minute particles which would otherwise render the liquid turbid.

2. Wine is sometimes clarified with albumen; the alcohol contained is sufficient to coagulate the albumen. The readiness with which albumen coagulates, is the reason why the process of boiling eggs is so soon accomplished.

747. *Gelatine* is a soft jelly-like substance, always abundant in young animals. It is contained in the head and feet of calves, and may be procured from almost any kind of meat by boiling. The skins of animals are chiefly gelatine, and it is largely contained in cartilages, tendons, membranes, and bones.

748. It is very soluble in boiling, and partially so in cold water. A concentrated hot solution on cooling, becomes more or less solid, con-

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746. What are the sources and uses of albumen?

747. Give the substance of observations 1 and 2.—What are the sources of gelatine, and how is it prepared?

748. What are the properties of gelatine and the names applied, and how is glue prepared?—What is isinglass?

stituting glue, size, or jelly, according to its consistence and the uses intended.

Obs. 1. Glue is made by boiling the ears, feet, and refused cuttings of the skins of animals in water, concentrating the solution to a certain extent, and when it begins to solidify, cutting it into slices, and drying it on net work stretched upon wooden frames.

2. Isinglass is also nearly pure gelatine; the scientific name of which is *ichthyocolla*. The best is obtained from fishes of the sturgeon kind, and is considerably used by the confectioners in preparing various jellies, and for clarifying liquids.

749. Gelatine, as was shown in the description of tannin, has the property of precipitating that substance from its solution in water, which in effect constitutes the process of *tanning*.

Illust. The skins composed of nearly pure gelatine in the solid state, being previously deprived of the hair, are immersed in water containing coarsely ground oak bark, and allowed to remain uutil the tannin of the bark has penetrated the whole thickness of the skin, and combining with its gelatine, converts the whole into leather.

750. *Animal oils*, or *oleaginous principles*, have different names, either from their consistence or from their sources; thus, *lard* is the fat of swine; *tallow* of neat cattle; *spermaceti* is the principle which is obtained from the head of the spermaceti whale, (*Physeter macrocephalus*,) and is much used in the manufacture of candles. It is obtained by subjecting the matter obtained from the head of the animal to pressure in bags, by which all the liquid mat-

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749. What is said of the action of gelatine on tannin, and what is its application?
750. What are the different oliaginous principles of animals?

ter is pressed out, and sold under the name of spermaceti oil, constituting the best lamp oil.

751. *Train oil*, more commonly called *whale oil*, is obtained by means of heat from the blubber of the whale, (chiefly the *Balœna mysticetus;*) hence the animal is often called the blubber whale. It is extensively employed in the preparation of oil gas, and for burning in common lamps. It has a reddish brown color, and a very disagreeable odor.

752. When either the train or spermaceti oil is exposed to cold, it separates into two parts, one of which is solid and remains at the bottom, while the other is liquid and floats on its surface. The former is called *stearine* and the latter *elaine*.

Obs. Stearine is the chief ingredient of the solid oleaginous principles, such as butter, lard, and suet, while the oils contain a large proportion of elaine. This last principle is much used by watchmakers to oil the wheels of watches.

753. Oils unite readily with alkalies as before shown, (507 and 517,) and form soaps in which the stearine and elaine are converted into two acids called the *magaric* and *oleic* acid, and a principle called *glycerine*.

Obs. Hence soap is in composition a true salt; potash soap is therefore a mixture of the *oleate* and *magarate* of potash, while soda, or hard soaps are compounds of the same acids with soda. Stearine, which exists in the solid matter of oils, is converted into *stearic acid* in the process for making soap.

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751. Give the sources, preparation, and uses of train oil.
752. Describe stearine and elaine, their preparation and uses.
753. What is said of magaric and oleic acid, and of the constitution of soaps?